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ABSTRACT

Economic Geography and International Inequality*

This Paper estimates a structural model of economic geography using cross-country data on *per capita* income, bilateral trade and the relative price of manufacturing goods. More than 70% of the variation in *per capita* income can be explained by the geography of access to markets and to sources of supply of intermediate inputs. These results are robust to the inclusion of other geographical, social and institutional characteristics. The estimated coefficients are consistent with plausible values for the structural parameters of the model. We find quantitatively important effects of distance, access to the coast and openness on levels of *per capita* income.

JEL Classification: F12, F14 and O10
Keywords: economic development, economic geography and international trade

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NON-TECHNICAL SUMMARY

This Paper poses a simple question: how much of the variation in the cross-country distribution of *per capita* income can be explained by countries' locations? We focus on two main forces. One is the distance of countries from the markets in which they sell output, and the other is distance from other countries that supply manufactures and that might provide the capital equipment and intermediate goods required for production. Transport costs or other barriers to trade mean that more distant countries suffer a market access penalty on their sales and also face additional costs on imported inputs. As a consequence, firms in these countries can only afford to pay relatively low wages – even if their technologies are the same as elsewhere.

The potential impact of these effects is easily illustrated. Suppose that the prices of output and intermediate goods are set on world markets, transport costs are borne by the producing country and intermediates account for 50% of costs. *Ad valorem* transport costs of 10% on both final output and intermediate goods have the effect of reducing domestic value added by 30% (compared to a country facing zero transport costs), the reduction in value added rising to 60% for transport costs of 20% and to 90% for transport costs of 30%.

We develop a theoretical trade and geography model to capture these effects, and use it to derive three key relationships for empirical study. The first is a gravity-like relationship for bilateral trade flows between countries. Estimation of this enables us to derive economically meaningful estimates of each country's proximity to markets and suppliers, which we call market access and supplier access. The second relationship is a break even condition for firms, which implicitly defines the maximum level of wages a representative firm in each country can afford to pay, given its proximity to markets and to suppliers. We call this the wage equation, and use it to estimate the relationship between actual wages (or *per capita* income levels) and the levels predicted by each country's market access and supplier access. The third relationship is a price index, suggesting how the prices of manufactures should vary with supplier access; we also estimate this, as a check on one of the key mechanisms in our approach.

We find that our measures of market access and supplier access are important determinants of manufacturing wages and *per capita* income, and that the estimated coefficients are consistent with plausible values for the structural parameters of the model. More than 70% of the cross-country variation in *per capita* income and more than 50% of the variation in manufacturing wages can be explained by the geography of access to markets and to sources of supply of intermediate inputs. The effects of features of economic geography on *per capita* income are shown to be quantitatively important. For example, access to the coast and openness yield predicted increases in *per capita* income of up to 60% and the hypothetical experiment of halving a country's distance from all its trade partners raises predicted *per capita* income by up to 75%, the effects being largest for small countries for whom the domestic market and domestic sources of supply are relatively unimportant.

We also establish that market access and supplier access remain important determinants of *per capita* income levels when we include other geographical, social and institutional characteristics of countries. These include regional effects; other geographical and political variables (such as prevalence of malaria, proximity to the tropics and socialist rule, as used by Gallup, Sachs and Mellinger, 1998); and the variables that Hall and Jones (1999) argue are ultimate determinants of social infrastructure (including distance from the equator and language mix). One of the mechanisms of our approach is that prices of intermediate goods are higher in countries remote from producers of manufacturing goods. We find a negative relationship between prices of machinery and equipment and our measure of supplier access, confirming the importance of this mechanism.

Our results may seem rather pessimistic for developing countries, suggesting that even if tariff and institutional obstacles to trade and investment are removed the penalty of distance will continue to hold down the incomes of remote regions. However, our results are derived for a given location of production and expenditure. As new markets and centres of manufacturing activity emerge, so the market and supplier access of neighbouring countries improves. Our results point to the importance of understanding the role of geography in shaping the evolution of the cross-country distribution of income.

1. Introduction

This paper poses a simple question. How much of the variation in the cross-country distribution of per capita income can be explained by countries' locations? Distance from other countries might affect per capita income through several routes; for example, it could retard the spread of new ideas and technologies. Here we base our study firmly on a new economic geography model (that of Fujita, Krugman, and Venables 1999) in which two mechanisms are important. One is the distance of countries from the markets in which they sell output, and the other is distance from countries that supply manufactures and that might provide the capital equipment and intermediate goods required for production. Transport costs or other barriers to trade mean that more distant countries suffer a market access penalty on their sales, and also face additional costs on imported inputs. As a consequence, firms in these countries can only afford to pay relatively low wages – even if their technologies are the same as elsewhere.

The potential impact of these effects is easily illustrated. Suppose that the prices of output and intermediate goods are set on world markets, transport costs are borne by the producing country, and intermediates account for 50% of costs. Ad valorem transport costs of 10% on both final output and intermediate goods have the effect of reducing domestic value added by 30% (compared to a country facing zero transport costs), the reduction in value added rising to 60% for transport costs of 20%, and to 90% for transports costs of 30%.[1] The model outlined in the paper captures these effects, and we use the exact specifications suggested by theory to estimate their magnitude and implications for wages. We show that more than 70% of the cross-country variation in per capita income and more than 50% of the variation in manufacturing wages can be explained by this model.

The methodology we employ is as follows. We develop a theoretical trade and geography model to derive three key relationships for empirical study. The first of these is a gravity-like relationship for bilateral trade flows between countries. Estimation of this enables us to derive economically meaningful estimates of each country's proximity to markets and suppliers -- measures that we call market access and supplier access respectively. Market access is essentially a measure of market potential, measuring the export demand each country faces given its geographical position and that of its trading partners. 'Supplier access' is the analogous measure on the import side, so is an appropriately distance weighted measure of the location of import supply to each country. The second relationship is a zero profit condition for firms, which implicitly defines the maximum level of wages a representative firm in each country can afford to pay, given its market access and supplier access. We call this the wage equation, and use it to estimate the relationship between actual wages (or per capita income levels) and levels predicted by each country's market access and supplier access. The third relationship is a price index, suggesting how the prices of manufactures should vary with supplier access; we also estimate this, as a check on one of the key mechanisms in our approach.

Throughout the paper we remain very close to the theoretical structure of the trade and geography model, seeking to show how much of the cross-country income variation can be explained simply by each country's location relative to other countries. We find that our market access and supplier access measures are important determinants of income, and that the estimated coefficients are consistent with plausible values for the structural parameters of the model. The effects of features of economic geography on per capita income are shown to be quantitatively important. For example, we find that access to the coast and openness yield predicted increases in per capita income of up to 60%, and halving a country's distance from all of its trade partners up to 75%, the effects being largest for small countries for whom the domestic market and domestic sources of supply are relatively unimportant. We also establish the robustness of our results with respect to the inclusion of other variables. These include regional dummies, other geographical and political variables (as used by Gallup, Sachs and Mellinger 1998), and the variables that Hall and Jones (1999) argue are ultimate determinants of social infrastructure (including distance from the equator and language mix).

The paper is structured as follows. In the next section, we set out the theoretical model and derive the three structural equations that form the basis of the econometric estimation. Section 3 discusses the empirical implementation of the model. Sections 4 and 5 estimate the trade equation and the wage equation respectively. In Section 6, we examine the robustness of the results to the inclusion of other variables. Section 7 extends the analysis using further data on manufacturing wages and manufacturing prices. Section 8 shows how the approach can be used to disentangle the effects of different features of economic geography for per capita income. Section 9 concludes.

2. Theoretical Framework

The theoretical framework is based on a standard new trade theory model, extended to have transport frictions in trade and intermediate goods in production.[2] The world consists of $r = 1,...R$ countries, and we focus on the manufacturing sector, composed of firms that operate under increasing returns to scale and produce differentiated products.[3]

On the demand side, each firm's product is differentiated from that of other firms, and is used both in consumption and as an intermediate good. In both uses there is a constant elasticity of substitution, σ, between pairs of products, so products enter both utility and production through a CES aggregator taking the form,

$$U_r = [\sum_s^R \int_{n_s} x_{sr}(i)^{(\sigma-1)/\sigma} di]^{\sigma/(\sigma-1)} = [\sum_s^R n_s x_{sr}^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)}, \qquad \sigma > 1, \tag{1}$$

where i denotes manufacturing varieties, n_s is the set of varieties produced in country s, and $x_{sr}(i)$ is the country r demand for the ith product from this set. The second equation makes use of the fact that, in equilibrium, all products produced in each country s are demanded by country r in the same quantity. We therefore dispense with the index i and rewrite the integral as a product. Dual to this quantity aggregator is a price index for manufactures in each country, G_r, defined over the prices of individual varieties produced in s and sold in r, p_{sr},

$$G_r = [\sum_s^R \int_{n_s} p_{sr}(i)^{1-\sigma} di]^{1/1-\sigma} = [\sum_s^R n_s p_{sr}^{1-\sigma}]^{1-\sigma} \tag{2}$$

where the second equation makes use of the symmetry in equilibrium prices.

Country r's total expenditure on manufactures we denote E_r. Given this expenditure, country r's demand for each product is, (by Shephard's lemma on the price index),

$$x_{sr} = p_{sr}^{-\sigma} E_r G_r^{(\sigma-1)}. \tag{3}$$

Thus, the own price elasticity of demand is σ, and the term $E_r G_r^{\sigma-1}$ gives the position of the demand curve facing a single firm in market r. We shall refer to this as the '*market capacity*' of country r; it depends on total expenditure in r and on the number of competing firms and the prices they charge, this summarised in the price index, G_r.

Turning to supply, a single representative country *s* firm has profits π_s,

$$\pi_s = \sum_r^R p_{sr} x_{sr} / T_{sr} - G_s^\alpha w_s^\beta v_s^\gamma c_s [F + x_s]. \tag{4}$$

The final term is costs. The total output of the firm is $x_s \equiv \sum_r x_{sr}$, and technology has increasing returns to scale, represented by a fixed input requirement $c_s F$ and marginal input requirement c_s, these technology parameters potentially varying across countries. The inputs required are a composite of primary factors and intermediate goods. We assume that this takes a Cobb-Douglas form with two primary factors, labour (with price w_s and input share β) and 'other primary factors' (with price v_s and input share γ), together with intermediate goods (with price G_s and input share α, $\alpha + \beta + \gamma = 1$).

The first term in (4) is revenue earned from sales in all markets. T_{sr} is an iceberg transport cost factor, so if $T_{sr} = 1$ then trade is costless, while $T_{sr} - 1$ measures the proportion of output lost in shipping from *s* to *r*. With demand function (3), profit maximising firms set a single f.o.b. price, p_s, so prices for sale in different countries are $p_{sr} = p_s T_{sr}$. The price, p_s, is a constant mark up over marginal cost, given by

$$p_s = \frac{\sigma}{\sigma - 1} G_s^\alpha w_s^\beta v_s^\gamma c_s. \tag{5}$$

Given this pricing behaviour, profits of a country *s* firm are,

$$\pi_s = \left(\frac{p_s}{\sigma}\right)\left[x_s - (\sigma - 1)F\right]. \tag{6}$$

Thus, the firm breaks even if the total volume of its sales equals a constant, which we shall denote $\bar{x} \equiv (\sigma - 1)F$. From the demand function, (3), it will sell this many units if its price satisfies[4]

$$p_s^\sigma = \left(\frac{1}{\bar{x}}\right) \sum_r^R E_r G_r^{\sigma - 1} (T_{sr})^{1-\sigma} \tag{7}$$

Substituting the profit maximising price of manufacturing varieties (equation (5)), firms break even if

$$\left(\frac{\sigma}{\sigma-1}G_s^{\alpha}w_s^{\beta}v_s^{\gamma}c_s\right)^{\sigma} = \left(\frac{1}{\bar{x}}\right)\sum_r^R E_r G_r^{\sigma-1}T_{sr}^{1-\sigma}. \qquad \mathbf{W} \qquad (8)$$

We call this the *wage equation* (W), and it constitutes a key relationship in the empirical analysis below. It says that the maximum level of costs -- including the wage -- that a firm in country *s* can afford to pay is a function of distance weighted market capacities.

The second relationship we use in the empirical analysis is that defining bilateral trade flows between countries. The demand equations (3) give the volume of sales per firm to each location, and expressing these in aggregate value gives exports from *s* to *r* of,

$$n_s p_s x_{sr} = n_s p_s^{1-\sigma}(T_{sr})^{1-\sigma}E_r G_r^{\sigma-1}. \qquad \mathbf{T} \qquad (9)$$

The right hand side of this equation contains both demand and supply variables. The term $E_r G_r^{\sigma-1}$ is country *r* market capacity, as defined above. On the supply side, the term $n_s p_s^{1-\sigma}$ measures what we refer to as the '*supply capacity*' of the exporting country; it is the product of the number of firms and their price competitiveness, such that doubling supply capacity (given market capacities) doubles the value of sales. In addition, the term $(T_{sr})^{1-\sigma}$ measures bilateral transport costs between countries.

The price index forms the third main relationship used in the empirical analysis to follow. This is already defined in equation (2), and given our assumption about transportation costs it becomes,

$$G_r = [\textstyle\sum_s n_s(p_s T_{sr})^{1-\sigma}]^{1/(1-\sigma)}. \qquad \mathbf{P} \qquad (10)$$

Notice that the term in square bracket is a sum of supply capacities, weighted by transport costs, so measures what we shall term the 'supplier access' of country *r*. It is important because an increase in this supplier access reduces the price index and the cost of intermediate goods, and therefore reduces the costs of production in country *r* (equation (8)).

Supplier access thus summarises the benefit of proximity to suppliers of intermediate goods.

The full general equilibrium of the model is explored in Fujita, Krugman and Venables (1999), and involves specifying factor endowments and hence factor market clearing to determine income and expenditure (E_r), the output levels of each country's manufacturing (the values of n_r) and output in other sectors (primary and non-tradable). Here we take E_r and n_r as exogenous and simply ask, given the locations of expenditure and of production, what wages can manufacturing firms in each location afford to pay?

3. Empirical Framework

The empirical analysis is derived directly from the theoretical framework outlined above, and proceeds in several stages. First, we estimate the trade equation (9) in order to obtain empirical estimates of bilateral transport costs between countries, and of each country's market and supply capacities. Labelling these M_r and S_s respectively, they are defined as

$$M_r \equiv E_r G_r^{\sigma-1}, \qquad S_s \equiv n_s p_s^{1-\sigma}, \tag{11}$$

and allow the trade equation (9) to be rewritten as,

$$n_s p_s x_{sr} = S_s (T_{sr})^{1-\sigma} M_r. \qquad \mathbf{T} \tag{12}$$

We estimate this gravity type relationship on bilateral trade flow data, using alternative measures of market and supply capacities and transport costs. From it we obtain predictions for $(T_{sr})^{1-\sigma} M_r$ and $S_s (T_{sr})^{1-\sigma}$ for each exporting country *s* and importing partner *r*.

Second, summing across importers, we construct variables measuring the market access of each exporting country *s*, MA_s, and, summing across exporters, the supplier access of an importing country *r*, SA_r. These are defined as

$$MA_s = \sum_r (T_{sr})^{1-\sigma} M_r, \qquad SA_r = \sum_s S_s (T_{sr})^{1-\sigma}. \tag{13}$$

Thus, market access is the appropriately distance weighted sum of the market capacities of all partner countries, and supplier access is the analogous sum of supplier capacities, measuring the proximity of an importing country *r* to suppliers of manufactures. Using predicted values of $(T_{sr})^{1-\sigma}M_r$ and $S_s(T_{sr})^{1-\sigma}$ from the trade equation, we construct empirical predictions for these two variables.

Third, using equations (8), (10), (11) and (13), the wage equation for country *s* can be written as a log-linear function of its supplier access and market access,

$$\left(w_s^{\beta} v_s^{\gamma} c_s\right)^{\sigma} = A G_s^{-\alpha\sigma} \sum_r^R E_r G_r^{\sigma-1} T_{sr}^{1-\sigma}$$

$$= A\left[\sum_r S_r (T_{sr})^{1-\sigma}\right]^{\frac{\alpha\sigma}{\sigma-1}} \left[\sum_r (T_{sr})^{1-\sigma} M_r\right] = A\left(SA_r\right)^{\frac{\alpha\sigma}{\sigma-1}} \left(MA_s\right) \qquad \textbf{W} \qquad (14)$$

where the left-hand side of equation (14) contains the wage, w_s, the prices of other factors of production, v_s, and a measure of technology differences, c_s; the constant *A* on the right-hand side combines constants from equation (8). The equation says that countries with high market access and high supplier access pay relatively high wages. We estimate this equation using predicted values of supplier access and market access as right hand side variables, and cross-country data on factor incomes as the dependent variable. This estimation establishes the extent to which observed variation in factor incomes can be explained by these geographical determinants, and the estimated coefficients on these variables can be clearly related to the values of the structural coefficients of the model.[5]

Finally, from equations (10) and (11), the price index for manufacturing goods, G_r, may be written as a function of supplier access, SA_r,

$$G_r = [SA_r]^{1/(1-\sigma)}. \qquad \textbf{P} \qquad (15)$$

We estimate equation (15) using predicted values of supplier access as the right-hand side variable and data on the relative price of manufacturing goods on the left-hand side.

4. Trade Equation Estimation

4.1 Data Sources and Sample Size

Data on bilateral trade flows for a cross-section of 101 countries are obtained from the World Bank's COMTRADE database. A country's market and supplier access depend on its trade with all other countries, and these trade data have the advantage of being available for a large cross-section of countries. We combine the trade data with information on geographical characteristics (eg bilateral distance, existence of a common border) and data on GDP and population from the World Bank. See Appendix A for further details.

4.2 Econometric Estimation

The value of bilateral trade flows in (12) depends upon exporting country characteristics (supply capacity, S_s), importing partner characteristics (market capacity, M_r), and bilateral transportation costs (T_{sr}). In the main econometric specification, these exporting and importing country characteristics (supply and market capacity) are captured with country and partner dummies (denoted by cty_s and ptn_r respectively). The use of dummies addresses the fact that we cannot observe economic variables that correspond exactly to the theory, and also controls for any component of transport costs or trade policy that is common across all partners for a particular exporting country or common across all suppliers of an importing country. Section 8 of the paper repeats the analysis using economic measures of supply and market capacity, and shows that the main results of the paper are robust to the use of either approach. The bilateral component of transportation costs is modelled using data on the distance between capital cities ($dist_{sr}$) and a dummy for whether an exporting country and importing partner share a common border ($bord_{sr}$). Equation (12) thus becomes,[6]

$$\ln(X_{sr}) = \alpha + \beta.cty_s + \gamma.ptn_r + \delta_1.\ln(dist_{sr}) + \delta_2.bord_{sr} + u_{sr} \qquad (16)$$

where X_{sr} denotes the value of exports from country s to partner r and u_{sr} is a stochastic error. There are a number of observations of zero bilateral trade flows and, throughout the following, we normalise the trade data by adding 1 before taking logarithms.[7]

Column (1) of Table 1 presents the results of estimating equation (16) on 1994 data using OLS. The distance between capital cities and common border variables are correctly signed according to economic priors and statistically significant at the 1% level. The null hypothesis that the coefficients on either the country dummies or the partner dummies are equal to zero is easily rejected at the 1% level with a standard F-test. The model explains approximately 80% of the cross-section variation in bilateral trade flows. However, the specification in column (1) does not take into account the fact that the trade data is left-censored at zero. In column (2), we re-estimate the model for the censored sample using OLS. Column (3) explicitly takes into account the truncated nature of the data by using the Tobit estimator. This increases the absolute magnitude of the coefficient on the distance variable and reduces the size of the coefficient on the common border dummy. We use the Tobit estimates as the basis for our next step.

Table 1 : Trade Equation (country, partner dummies)

$\ln(X_{sr})$	(1)[a]	(2)[a]	(3)[b]
Obs	10100	8079	10100
Year	1994	1994	1994
$\ln(dist_{sr})$	-1.538	-1.353	-1.738
	(0.041)	*(0.032)*	*(0.043)*
$bord_{sr}$	0.976	1.042	0.917
	(0.195)	*(0.141)*	*(0.179)*
Country dummies	yes	yes	yes
Partner dummies	yes	yes	yes
Estimation	OLS	OLS	Tobit
F(·)	249.63	159.67	-
Prob > F	0.000	0.000	-
R-squared	0.789	0.786	-
Root MSE	2.214	1.688	-
Log Likelihood	-	-	-20306.379
LR $\chi^2(206)$	-	-	15231.38
Prob > χ^2	-	-	0.000
Pseudo R^2	-	-	0.273

Notes: [a] Huber-White heteroscedasticity robust standard errors in parentheses, [b] 2021 left-censored observations <=0, 8079 uncensored observations.

The values of the country and partner dummies in the trade equation (16) provide estimates of the market and supply capacities of each country, M_r and S_s, and the distance and border coefficients provide estimates of the bilateral transport cost measure, $(T_{sr})^{1-\sigma}$. We can use these to construct predicted values of market access and supplier access, as defined in equation (13), and taking the form:

$$M\hat{A}_s = D\hat{M}A_s + F\hat{M}A_s = (\exp(ptn_s))^{\hat{\gamma}}\left(T_{ss}\right)^{1-\sigma} + \sum_{r \neq s} (\exp(ptn_r))^{\hat{\gamma}}.dist_{sr}^{\hat{\delta}_1}.bord_{sr}^{\hat{\delta}_2} \quad (17)$$

$$S\hat{A}_r = D\hat{S}A_r + F\hat{S}A_r = (\exp(cty_r))^{\hat{\beta}}\left(T_{rr}\right)^{1-\sigma} + \sum_{s \neq r} (\exp(cty_s))^{\hat{\beta}}.dist_{sr}^{\hat{\delta}_1}.bord_{sr}^{\hat{\delta}_2} \quad (18)$$

Notice that we have split each of these into a domestic and foreign part (DMA and FMA respectively). The reason is that the trade equation does not provide us with estimates of ‘intra-country’ transport cost measures, $(T_{ss})^{1-\sigma}$. We consider three alternative ways of getting hold of these measures. First, we assume that internal trade costs are equal to the cost of shipping to a foreign country 100km away and with a common border; using these we develop series $D\hat{M}A_s(1)$ and $D\hat{S}A_r(1)$.[8] Second, we link intra-country transport costs to the area of the country, by using the formula $dist_{ss} = 0.33(area/\pi)^{1/2}$, to give the average distance between two points in a circular country. We construct series $D\hat{M}A_s(2)$ and $D\hat{S}A_r(2)$ using $T_{ss}^{1-\sigma} = dist_{ss}^{\hat{\delta}_1}$. Third, to capture the likelihood that internal transport costs are less than international, we construct series $D\hat{M}A_s(3)$ and $D\hat{S}A_r(3)$ using $dist_{ss}^{\hat{\delta}_1/2}$.

5. Wage Equation Estimation

Having obtained predicted values for market and supplier access, we move on to the econometric estimation of the wage equation. From equation (14), factor incomes in country s are related to market and supplier access as follows,

$$\beta.\ln w_s = \xi + \varphi_1.\ln SA_s + \varphi_2.\ln MA_s + \eta_s, \quad (19)$$

and substituting predicted for actual values of market and supplier access, we obtain,

$$\log w_s = \zeta + \varphi_1.\ln S\hat{A}_s + \varphi_2.\ln M\hat{A}_s + \varepsilon_s \tag{20}$$

Before presenting estimates of this equation, a number of issues merit discussion. First, the stochastic error in (19), η_s, includes differences in the prices of other factors of production, $\ln(v_s)$, and exogenous differences in technology across countries, $\ln(c_s)$. If capital is internationally mobile then $v_s = v$ for all s, and the rate of return to capital is captured in the constant. In consigning exogenous technology differences to the residual, we do not mean to imply that these are unimportant.[9] The spirit of the paper is to take a structural model of economic geography seriously and examine how much of the variation in cross-country per capita income can be explained simply by countries' locations relative to one another -- without having to resort to exogenous technology differences. We begin by assuming that any cross-country differences in technology and/or in the price of other factors of production contained in the residual are uncorrelated with the explanatory variables. We return to these differences in Section 6 of the paper, which explicitly considers the role of a series of other geographical, social and institutional variables which have been proposed as fundamental determinants of technology and/or factor prices in the cross-country growth literature. The inclusion of these variables controls for unobserved variation across countries in technology and/or other factor prices. We show that our empirical findings with regard to market and supplier access are robust to their inclusion.

Second, since the predicted values for market and supplier access are generated from a prior regression (the trade equation), the stochastic error in equation (20), ε_s, includes the trade equation residuals. The presence of generated regressors (Pagan (1984)) means that, as in Two Stage Least Squares, the OLS standard errors are invalid. We employ Bootstrap Techniques (Efron (1979), (1981) and Efron and Tibshirani (1993)) to obtain standard errors that explicitly take into account the presence of generated regressors.[10]

Third, consistent estimation of the parameters φ_1 and φ_2 requires that shocks to the independent variable, manufacturing wages, are uncorrelated with the predicted values for market and supplier access obtained from the trade equation. With a positive income elasticity of import demand, shocks to manufacturing wages in countries s and r will affect current and (if there is partial adjustment) future values of bilateral trade. To address this, we estimate the trade equation using 1994 data and the wage equation using 1996 data.[11] The predicted values for market and supplier access in 1994 are pre-determined with respect to manufacturing wages in 1996. However, pre-determination is not sufficient for weak exogeneity, as agents may be able to systematically predict future shocks to manufacturing wages.[12] We therefore also provide estimates using instrumental variables. The instruments for market and supplier access are distance from the three centres of world economy activity (the United States, France as a central point in the European Union, and Japan), whether a country is land-locked or not, and whether a country is an island or not. These are purely geographical determinants of market and supplier access and will be uncorrelated with shocks to manufacturing wages.

We estimate (20) using two alternative wage measures. In this section, we use data on GDP per capita as a proxy for manufacturing wages (more generally, this variable may also control for the price of other primary factors of production used in manufacturing, v_s). The data on GDP per capita are from the World Bank, and have advantage of being available for all 101 countries included in the trade equation estimation. In section 7, we present alternative estimates using data on the actual wage per worker in total manufacturing from the UNIDO Industrial Statistics Database, for a sub-sample of 62 countries.

Finally, predicted market and supplier access are, in practice, highly correlated. Therefore, we begin by regressing the log manufacturing wage on market access and supplier access separately. In section 7 of the paper, we include both measures and exploit a theoretical restriction on the relative value of the estimated coefficients.

Table 2: Market Access and GDP per capita[a]

ln*(GDP per capita)*	(1)[b],[c]	(2)[b],[c]	(3)[b],[c]	(4)[b],[c]	(5)[b],[c]
Obs	101	101	101	101	101
Year	1996	1996	1996	1996	1996
$\ln(FMA_s)$	0.476	-	-	-	0.316
	(0.066)				*(0.066)*
	[0.076]				*[0.088]*
$\ln(MA_s) = \ln(DMA_s(1) + FMA_s)$	-	0.558	-	-	-
		(0.042)			
		[0.064]			
$\ln(MA_s) = \ln(DMA_s(2) + FMA_s)$	-	-	0.479	-	-
			(0.044)		
			[0.063]		
$\ln(MA_s) = DMA_s(3) + FMA_s)$	-	-	-	0.373	-
				(0.022)	
				[0.032]	
$\ln(DMA_s(3))$	-	-	-	-	0.141
					(0.037)
					[0.059]
Estimation	OLS	OLS	OLS	OLS	OLS
R^2	0.346	0.642	0.610	0.727	0.584
F(·)	52.76	174.46	121.21	299.90	47.78
Prob>F	0.000	0.000	0.000	0.000	0.000

Notes: [a] first stage estimation of the trade equation using Tobit (column (3) in Table 1). [b] Huber-White heteroscedasticity robust standard errors in parentheses. [c] Bootstrapped standard errors in square parentheses (200 replications).

Column (1) of Table 2 presents the results of regressing log GDP per capita on predicted *foreign* market access using OLS. The estimated coefficient on foreign market access is positive and statistically significant at the 5% level. Taking into account the presence of generated regressors raises the standard error of the estimated coefficient, but this remains highly statistically significant. Foreign market access alone explains approximately 35% of the cross-country variation in GDP per capita. In column (2), we include total market access (foreign plus domestic), using our first measure of domestic market access. The estimated coefficient is again positive and statistically significant at the 5% level, and the R^2 of the regression rises to 0.64. In columns (3) and (4), cross-country variation in internal area is incorporated in the construction of DMA, corresponding to our second and third measures. Estimated coefficients are positive and statistically significant at the 5% level, and with DMA(3) the model explains 73% of the cross-country variation in GDP per capita. Finally, as a robustness test, column (5) enters log foreign and log domestic market access (DMA(3)) as separate terms in the regression equation. Theory tells us that this regression is mis-specified, and we see that the R^2 is lower than with the correct specification (column (4)). However, both terms are positively signed and statistically significant at the 5% level.

Figures 1 to 4 plot log GDP per capita against the four alternative measures of log market access considered in columns (1) - (4) of Table 2. Each country is indicated by a three letter code (see Appendix A for details). It is clear from these figures that the relationship between GDP per capita and market access is very robust, and is not due to the influence of a few individual countries. In Figure 1, using FMA alone, the main outliers are remote high per capita income countries (Australia, New Zealand, Japan and the USA). Remaining figures add in estimates of DMA, as required by theory, and each illustrates a different treatment of the internal transportation costs. In Figure 2, DMA is included with the same measure of internal transport costs for all countries – which seems to make large countries outliers to the right (India, China, USA) and small ones outliers to the left (eg Israel), exactly as would be expected. Letting internal transport costs vary with area, and treating internal distance identically to external distance (Figure 3) seems to over-compensate – Singapore and Hong Kong come to have much better market access than Germany or the USA. In Figure 4, we let internal transport costs vary with area, but allow the costs of transporting goods a given distance internally to be lower than for the same external distance. This is the solution which produces the best fit, as well as according with economic priors on the relative magnitudes of internal and external transport costs.

<Figures 1-4 about here>

Table 3 presents the results of instrumental variables estimation. The distance variables capture access to the three largest markets and sources of supply for manufacturing goods. They will be correlated with the more sophisticated measures of market and supplier access obtained from the trade equation but uncorrelated with shocks to manufacturing wages. The costs of transportation by sea or ocean are substantially lower than those by land, and a large development literature emphasises the importance of coastlines and ports in facilitating market and supplier access. The final two instruments are therefore a dummy for whether or not a country is land-locked and a dummy for whether or not a country is an island. In the trade equation, these characteristics of countries and their trade partners are captured in the country dummies and partner dummies. The land-locked and island variables will again be correlated with the measures of market and supplier access derived from the trade equation but uncorrelated with shocks to manufacturing wages.

Column (1) of Table 3 reports the results of regressing log GDP per capita on our preferred measure of market access (MA(3)) using Two Stage Least Squares. The estimated coefficient on market access is very close to that obtained using OLS (Column (4) of Table 2) and remains highly statistically significant. The lower section of Table 3 reports the results of a Hausman specification test. We are unable to reject the null hypothesis that OLS is consistent and efficient at the 5% critical value. That is, we find no evidence that our measure of market access is endogenous with respect to shocks to manufacturing wages. This finding is consistent with the point made earlier, that the measure of market access included in the wage equation is based on 1994 bilateral trade flows and is therefore pre-determined. Columns (2) and (3) in Table 3 present the reduced-form regressions underlying the Two Stage Least Squares estimates reported in Column (1). Since they are reduced-forms, these regressions do not have a structural interpretation. Nonetheless, each of the coefficients on the exogenous variables is signed according to economic priors. The R^2 in the market access (MA(3)) regression is 0.44, indicating a close relationship between the instruments and the theory-consistent measure of market access obtained from the trade equation.

Table 3: Market Access and GDP per capita (Instrumental Variables Estimation)[(a)]

	(1)[(b),(c),(d)]	(2)[(b)]	(3)[(b)]
Obs	101	101	101
Year	1996	1996	1996
	Dependent variables		
Regressors	ln(GDP per capita)	ln(MA_s(3))	ln(GDP per capita)
ln(MA_s = DMA_s(3) + FMA_s)	0.371	-	-
	(0.030)		
	[0.050]		
ln(Distance from USA)[(e)]	-	-0.574	-0.269
		(0.103)	*(0.069)*
ln(Distance from France)	-	-0.773	-0.349
		(0.181)	*(0.099)*
ln(Distance from Japan)	-	-0.853	-0.226
		(0.266)	*(0.073)*
Land-locked	-	-1.848	-0.617
		(0.455)	*(0.234)*
Island	-	1.040	0.406
		(0.597)	*(0.313)*
OLS estimate	0.373	-	-
	(0.022)		
	[0.032]		
Hausman test (*p*-value)	0.918	-	-
	(Accept)		
Estimation	IV	OLS	OLS
R^2	0.727	0.439	0.333
F(·)	158.20	21.06	10.68
Prob>F	0.000	0.000	0.000

Notes: [(a)] first stage estimation of the trade equation using Tobit (column (3) in Table 1). [(b)] Huber-White heteroscedasticity robust standard errors in parentheses. [(c)] Bootstrapped standard errors in square parentheses (200 replications). [(d)] Endogenous variable: $MA_s(3)$; Exogenous variables: Distance from USA, Distance from France, Distance from Japan, Land-locked, and Island. [(e)] ln(Distance from USA) is defined as ln(1+Distance from USA), where distance takes the value zero for the USA. The other distance variables are defined analogously.

6. Robustness of Results

The paper adopts an approach which is both parsimonious and theory based. We now proceed to examine the robustness of results to the inclusion of a whole series of variables which control for unobserved variation across countries in technology and/or the price of other factors of production. Each of these variables has been proposed as an exogenous or fundamental determinant of levels of income per capita in the empirical growth literature.

The conventional approach in that literature takes as its starting point the Solow-Swan neoclassical model of growth. Many studies either directly analyse the relationship between factor inputs and aggregate output (as in the growth accounting approach of Benhabib and Spiegel (1994)) or examine the model's predictions for the steady-state levels of income per capita (as in the seminal work by Mankiw, Romer, and Weil (1992)). The wage equation we estimate is an equilibrium relationship between manufacturing wages, market access, and supplier access, that is derived from profit maximisation and zero profits. An essential feature of the analysis is the presence of multiple varieties of manufacturing goods, which are themselves used as intermediate inputs in manufacturing production. This gives an input-output structure to the model. Proximity to markets and sources of supply matters because it affects the maximum wage that a manufacturing firm in a particular location can afford to pay consistent with zero equilibrium profits. Many of the variables considered in the aggregate production function approach (eg rates of investment in physical and human capital) will themselves be endogenous to economic geography. The spirit of the analysis is close to Hall and Jones (1998), in the sense that we are concerned with exogenous or fundamental determinants of *levels* of income per capita.

The first set of exogenous control variables we consider are the features of *physical* geography and institutional, social, and political characteristics emphasised in the work of Gallup, Sachs, and Mellinger (1998). The availability of the Gallup *et al.* data reduces the sample to 99 countries[13], and results are presented in Table 4. Column (1) presents the results of re-estimating the specification in column (4) of Table 2 for the reduced sample. The estimated coefficient on market access (MA(3)) is barely changed. In Column (2) of Table 4, we introduce physical geography characteristics: log hydrocarbons per head, the fraction of a country's land area in the geographical tropics, and an index of the prevalence of Malaria. All variables are signed according to economic priors, although only the prevalence of

Malaria is statistically significant at the 5% level. This finding is entirely consistent with the model presented here if the effect of Malaria is to reduce levels of technical efficiency, as indeed suggested by Gallup *et al.*. The coefficient on market access remains positive, is of a similar magnitude, and is highly statistically significant.

Table 4: Market Access, GDP per capita, and Physical Geography[(a)]

ln(*GDP per capita*)	(1)[(b)]	(2)[(b)]	(3)[(b)]	(4)[(b)]	(5)[(b)]
Obs	99	99	99	99	99
Year	1996	1996	1996	1996	1996
$\ln(FMA_s)$	-	-	-	0.264	0.277
				[0.078]	*[0.063]*
$\ln(MA_s = DMA_s(3) + FMA_s)$	0.369	0.288	0.274	-	-
	[0.032]	*[0.027]*	*[0.038]*		
ln(Hydrocarbons per capita)	-	0.019	0.019	0.028	0.026
		[0.018]	*[0.018]*	*[0.017]*	*[0.016]*
Fraction Land in Geog. Tropics	-	-0.163	-0.190	0.031	-0.139
		[0.159]	*[0.203]*	*[0.243]*	*[0.253]*
Prevalence of Malaria	-	-0.910	-0.945	-1.601	-1.496
		[0.298]	*[0.310]*	*[0.266]*	*[0.268]*
Socialist Rule 1950-95	-	-	-0.109	-	-0.743
			[0.208]		*[0.156]*
External War 1960-85	-	-	-0.099	-	-0.344
			[0.195]		*[0.170]*
Estimation	OLS	OLS	OLS	OLS	OLS
R^2	0.723	0.815	0.818	0.560	0.671
F(·)	288.95	124.71	100.61	55.61	55.63
Prob>F	0.000	0.000	0.000	0.000	0.000

Notes: [(a)] first stage estimation of the trade equation using Tobit (column (3) in Table 1).
[(b)] Bootstrapped standard errors in square parentheses (200 replications).

Column (3) of Table 4 extends the specification to introduce institutional, social, and political factors addition to the physical geography characteristics. We consider the effect of dummies for socialist rule during 1950-95 and the occurrence of an external war during 1960-85. Both variables are signed according to economic priors, although neither is statistically significant at the 5% level. The coefficient on market access again remains positive, is of a similar magnitude, and is highly statistically significant. Columns (4) and (5) report the results of including these control variables in the specification with foreign market access alone. A similar pattern of results is observed.

The second set of exogenous controls are the fundamental determinants of social infrastructure used by Hall and Jones (1998): distance from the equator, the fraction of the population speaking English, and the fraction of the population speaking a European language.[14] The Hall and Jones data are available for 86 of the 101 countries in our dataset.[15] Column (1) of Table 5 presents the results of re-estimating the specification in Column (4) of Table 2 for the reduced sample and gives similar results. In Column (2) of Table 5, we introduce distance from the equator, the fraction of the population speaking English, and the fraction of the population speaking a European language. All variables are signed according to economic priors, and distance from the Equator and fraction of the population speaking a European language are statistically significant at the 5% level. These findings are consistent with the model presented earlier. It is plausible that distance from the equator and the fraction of the population speaking a European language affect levels of technical efficiency (see Hall and Jones (1998) for further discussion). The estimated coefficient on market access remains positive, is of a similar magnitude, and is highly statistically significant.

Columns (3) and (4) report the results of including these control variables in the specification with foreign market access. The estimated coefficient on foreign market access is reduced, but remains positive and statistically significant at the 5% level. This suggests the importance of controlling for domestic as well as foreign market access (the size of the domestic market will vary between large and small countries at similar degrees of latitude). Leaving domestic market considerations to one side, the fall in the estimated coefficient on *foreign* market access suggests that some of the variation in foreign market access used to identify this parameter is between regions near to and far from the equator. In the absence of technology differences, the model implies that distance from the equator matters simply because it changes distance to markets and sources of supply.[16] In practice, as discussed above, there may be additional effects (eg changes in climate and the prevalence of disease which influence technical efficiency), and it is likely to be hard to separately identify these additional effects from the pure economic geography considerations emphasised in our analysis. Nonetheless, even if we exclude all variation in foreign market access associated with distance from the equator, we find a substantial and statistically significant effect of foreign market access on GDP per capita.

Table 5: Market Access, GDP per capita, and Social Infrastructure[(a)]

ln*(GDP per capita)*	(1)[(b)]	(2)[(b)]	(3)[(b)]	(4)[(b)]
Obs	86	86	86	86
Year	1996	1996	1996	1996
$\ln(FMA_s)$	-	-	0.528	0.232
			[0.085]	*[0.103]*
$\ln(MA_s) = \ln(DMA_s(3) + FMA_s)$	0.392	0.312	-	-
	[0.033]	*[0.040]*		
Distance from Equator, (0,1) scale[(c)]	-	1.556	-	2.546
		[0.612]		*[0.794]*
Fraction pop. speaking English	-	0.009	-	0.409
		[1.044]		*[0.330]*
Fraction pop. speaking a European language	-	0.558	-	0.752
		[0.197]		*[0.181]*
Estimation	OLS	OLS	OLS	OLS
R^2	0.746	0.821	0.361	0.537
F(·)	310.78	84.20	53.50	32.83
Prob>F	0.000	0.000	0.000	0.000

Notes: [(a)] first stage estimation of the trade equation using Tobit (column (3) in Table 1). [(b)] Bootstrapped standard errors in square parentheses (200 replications). [(c)] Distance from the Equator is measured, as in Hall Jones (1998), by |latitude|/90.

Finally, we consider the robustness of a results to the inclusion of dummy variables for the following economic regions: Africa, Latin America and the Caribbean, South East Asia, Other Asia, Eastern Europe and the former USSR, and the Middle-East.[17] Column (1) of Table 6 reproduces the estimation results from Column (4) of Table 2, and in column (2) we include dummies for the six economic regions (the excluded category is the industrialised countries of North America, Western Europe, and Oceania). The estimated coefficients on all dummy variables are negative, as is expected given the excluded category and the fact that this is a regression for *levels* of per capita income. The dummies for Africa, South-east Asia, and Other Asia are statistically significant at the 5% level. The coefficient on market access remains positive, is of a similar magnitude, and is highly statistically significant.

Table 6: Market Access, GDP per capita, and Regional Effects[(a)]

ln*(GDP per capita)*	(1)[(b)]	(2)[(b)]	(3)[(b)]	(4)[(b)]
Obs	101	101	101	101
Year	1996	1996	1996	1996
$\ln(FMA_s)$	-	-	0.476	0.202
			[0.076]	*[0.062]*
$\ln(MA_s) = \ln(DMA_s(3) + FMA_s)$	0.373	0.328	-	-
	[0.032]	*[0.053]*		
Africa	-	-0.784	-	-1.974
		[0.367]		*[0.231]*
Latin America and Carribean	-	-0.213	-	-1.003
		[0.270]		*[0.185]*
South East Asia	-	-0.802	-	-0.382
		[0.284]		*[0.309]*
Other Asia	-	-1.060	-	-2.015
		[0.470]		*[0.211]*
Eastern Europe and former USSR	-	-0.055	-	-1.213
		[0.279]		*[0.149]*
Middle-East	-	-0.325	-	-1.192
		[0.578]		*[0.556]*
Estimation	OLS	OLS	OLS	OLS
R^2	0.727	0.830	0.346	0.673
$F(\cdot)$	299.90	62.51	52.76	53.45
Prob>F	0.000	0.000	0.000	0.000

Notes: [(a)] first stage estimation of the trade equation using Tobit (column (3) in Table 1).
[(b)] Bootstrapped standard errors in square parentheses (200 replications).

Columns (3) and (4) of Table 6 repeat this analysis for *foreign* market access alone. The estimated coefficients on the dummy variables are again all negative, and, with the exception of South East Asia, each is statistically significant at the 5% level. The estimated coefficient on foreign market access is reduced (confirming the importance of controlling for domestic market access which varies substantially across countries *within* each economic grouping), but remains positive and statistically significant at the 5% level. Thus, even if we focus solely on variation *within* economic regions, we find a positive and statistically significant effect of market access on levels of per capita income.

7. Manufacturing Wages and Prices

In this section we make three extensions to our analysis. First, we re-estimate using manufacturing wage data rather than per capita income data. Second, we include both market access and supplier access in our estimation of the wage equation. And third, we present some independent evidence that one of the key mechanisms of our approach is important, namely that manufacturing prices do vary with predicted supplier access.

7.1 Manufacturing wages.

The manufacturing wage per worker corresponds more closely to the theoretical model than does GDP per capita, (although the latter may also capture the price of other primary factors of production used in manufacturing). Manufacturing wage data are available for 62 of the countries included in our sample (see Appendix A for further details). In Table 7, we re-estimate the wage equation using manufacturing wage data; the results are very similar. The estimated coefficient on log foreign market access in column (1) is positive and statistically significant at the 5% level. Columns (2) - (4) combine foreign and domestic market access. The explanatory power of the model rises and, as before, specification DMA(3) produces the best fit, with market access explaining approximately 57% of the cross-country variation in wage rates. When log foreign and log domestic market access are entered separately (column (4)) the estimated coefficients are both positive and statistically significant at the 5% level. Comparing results in Table 7 with those in Table 2, we see that the coefficients using data on manufacturing wages are larger than those when using GDP per capita. This is as would be expected if labour is immobile, while other factors included in GDP (such as capital) are mobile and have the cross-country variation in returns reduced by international factor mobility.

Figures 5-6 plot the log manufacturing wage against log foreign market access and log market access (just for DMA(3)). A similar pattern of results is observed to those using GDP per capita. When only foreign market access is considered, Argentina, New Zealand, and the USA are all outliers with high levels of manufacturing wages relative to their foreign market access. When our measures of domestic market access are included, these countries cease to be outliers, and we observe a concentration of advanced industrialised countries in the upper right hand corner of Figures 5 and 6.

<Figures 5-6 about here>

Table 7: Market access and manufacturing wage per worker[(a)]

ln(*Manufacturing wage per worker*)	(1)[(b)]	(2)[(b)]	(3)[(b)]	(4)[(b)]	(5)[(b)]
Obs	62	62	62	62	62
Year	1996	1996	1996	1996	1996
$\ln(FMA_s)$	0.612	-	-	-	0.352
	[0.129]				*[0.147]*
$\ln(MA_s) = \ln(DMA_s(1) + FMA_s)$	-	0.688	-	-	-
		[0.126]			
$\ln(MA_s) = \ln(DMA_s(2) + FMA_s)$	-	-	0.582	-	-
			[0.122]		
$\ln(MA_s) = \ln(DMA_s(3) + FMA_s)$	-	-	-	0.471	-
				[0.075]	
$\ln(DMA_s(3))$	-	-	-	-	*0.236*
					[0.094]
Estimation	OLS	OLS	OLS	OLS	OLS
R^2	0.314	0.511	0.466	0.574	0.553
$F(\cdot)$	28.73	55.75	37.97	71.19	24.70
Prob>F	0.000	0.000	0.000	0.000	0.000

Notes: [(a)] first stage estimation of the trade equation using Tobit (column (3) in Table 1).
[(b)] Bootstrapped standard errors in square parentheses (200 replications).

7.2 Market access and supplier access.

Our theory suggests that both market access and supplier should be in the wage equation, but because of the high degree of correlation between the two series we have so far used only market access.[18] Table 8 extends the analysis to incorporate information on supplier access, SA_r. For brevity, we consider only the results with the manufacturing wage per worker and our third measures of domestic market and supplier access. The first column gives the relationship between the wage and total market access, reproduced from column (4) of Table 7. The second column presents the relationship between the wage and supplier access. The estimated coefficient on supplier access is positive and statistically significant at the 5% level, and explains 52% of the cross-country variation in the manufacturing wage per worker.

The theoretical model of section 2 implies that manufacturing wages depend upon *both* market access and supplier access. It is therefore hard to give a structural interpretation to the estimated coefficients on these variables when they are entered separately in columns (1) and (2), while the high degree of correlation between the two variables means that it is difficult to separately identify their individual effects. However, we can exploit a theoretical restriction on the relative magnitude of the estimated coefficients on market and supplier access. From equation (14), the estimated values of φ_1 and φ_2 in (20) are related to the structural parameters of the model as follows,

$$\varphi_1 = \frac{\alpha}{\beta(\sigma-1)}, \qquad \varphi_2 = \frac{1}{\beta\sigma}, \qquad \textit{implying} \quad \varphi_1 = \varphi_2 \alpha\sigma/(\sigma - 1) \tag{21}$$

Thus, if we select values of α and σ (the cost share of intermediates and the elasticity of substitution between varieties), a linear restriction is imposed on the values of φ_1 relative to φ_2. We estimate (20) subject to this restriction, for a series of different values of α and σ. From the estimated value of φ_2, we then compute the implied value of β (the share of labour in unit costs). Values of α and σ are reported in rows and columns of Table 9, and the implied values of β are in the body of table. The full estimation results are presented in columns (3) - (5) of Table 8, just for the cases that lie on the diagonal of Table 9.

Inspection of the results reported in columns (3) - (5) of Table 8 indicates that the estimated coefficient on supplier access, φ_1, ranges from 0.15 to 0.19 (implying an estimated coefficient on market access, φ_2, between 0.28 to 0.32) and is statistically significant at the 5% level. The model explains approximately 57% of the cross-country variation in the manufacturing wage. The implied parameter values given in Table 9 indicate, for example, that an intermediate share of 50% ($\alpha = 0.5$) and elasticity of substitution of 8 is consistent with a labour share of 42% ($\beta = 0.42$) (or 84% of value added). If the elasticity of substitution is raised to 10 then the implied labour share is 33% (66% of value added). These parameter values are broadly consistent with direct empirical estimates.

Table 8: Market access, supplier access and the manufacturing wage.[(a)]

ln*(Manufacturing wage per worker)*	(1)[(b)]	(2)[(b)]	(3)[(b)]	(4)[(b)]	(5)[(b)]
Obs	62	62	62	62	62
Year	1996	1996	1996	1996	1996
α			0.4	0.5	0.6
σ			6	8	10
$\ln(MA_s) = \ln(DMA_s(3) + FMA_s)$	0.471	-	0.317	0.298	0.281
	[0.075]				
$\ln(SA_r) = \ln(DSA_r(3) + FSA_r)$	-	0.432	0.152	0.170	0.187
		[0.075]	*[0.025]*	*[0.028]*	*[0.031]*
Estimation	OLS	OLS	OLS	OLS	OLS
R^2	0.574	0.525	0.570	0.569	0.567
F(·)	71.19	62.77	68.36	68.04	67.72
Prob>F	0.000	0.000	0.000	0.000	0.000

Notes: [(a)] first stage estimation of the trade equation using Tobit (column (3) in Table 1).
[(b)] Bootstrapped standard errors in square parentheses (200 replications).

Table 9: Implied values of labour share (*β*) for different values of intermediate share (α) and demand elasticity (σ) [(a)]

α	0.4	0.5	0.6
σ = 6	0.526 *(φ_2=0.317)*	0.571 *(φ_2=0.292)*	0.615 *(φ_2=0.271)*
σ = 8	0.386 *(φ_2=0.324)*	0.419 *(φ_2=0.298)*	0.451 (φ_2=0.277)
σ = 10	0.309 *(φ_2=0.324)*	0.334 *(φ_2=0.299)*	0.356 *(φ_2=0.281)*

Notes: [(a)] The values of β are derived from the formula for φ_2 in equation (21) and the parameter estimates in Table 8 for given values of α and σ.

7.3 Manufacturing Prices

The model implies a relationship between supplier access, SA_r, and the manufacturing price index, G_r, taking the form $G_r = [SA_r]^{1/(1-\sigma)}$ (equation (15)). Since some data is available on measures of cross-country variation in manufacturing prices, we now look to see if this evidence is consistent with our model. To what extent can cross-country variations in manufacturing prices be explained by economic geography?

Our empirical proxy for G_r is the relative price of Machinery and Equipment. The latter is an important manufacturing sector, whose output is used as an input in many other industries.[19] The data on the relative price of Machinery and Equipment are obtained from Phase V of the United Nations International Comparisons (ICP) project (United Nations (1994)). This contains information on the price of a large number of individual commodities in local currency units per dollar. These commodity-specific Purchasing Power Parities (PPPs) are also aggregated to derive corresponding PPPs for particular industries and for GDP as a whole. Our measure of the relative price of Machinery and Equipment is thus the PPP for Machinery and Equipment divided by the PPP for GDP. This is a measure for each country of the relative price of the industry's output in terms of GDP. The data are available for the cross-section of countries listed in Appendix A and are for 1985. The relative price of Machinery and Equipment is 1 in the United States, has a low of 0.64 in France, and rises to 4.68 in Sri Lanka.

We regress the relative price of Machinery and Equipment against our measure of supplier access, SA_r, and results are presented in Table 10. Column (1) considers foreign supplier access, FSA_r, alone, while column (2) introduces both domestic and foreign supplier access using our third measure of supplier access. Column (3) presents the results excluding Tanzania, which, as will be seen further below, is a clear outlier. In all three columns, the estimated coefficient on supplier access is negative and statistically significant at the 5% level. As predicted by the theoretical model, countries with high levels of supplier access are characterised by a lower relative price of Machinery and Equipment. Furthermore, the coefficients reported in columns (1) and (3) imply estimated values of σ of 5.67 and 13.82 respectively, numbers which are broadly consistent with existing empirical estimates.

Table 10: The relative price of Machinery and Equipment and supplier access[(a)]

ln*(Mach and equip relative price)*	(1)[(b)]	(2)[(b)]	(3)[(b)]
Obs	46	46	45
Year	1985	1985	1985
$\ln(FSA_r)$	-0.150	-	-
	[0.060]		
$\ln(SA_r = DSA_r(3) + FSA_r)$	-	-0.066	-0.079
		[0.029]	*[0.024]*
Estimation	OLS	OLS	OLS
R^2	0.260	0.184	0.273
F(·)	19.31	13.57	29.32
Prob>F	0.000	0.000	0.000

Notes: [(a)] first stage estimation of the trade equation using Tobit (column (3) in Table 1).
[(b)] Bootstrapped standard errors in square parentheses (200 replications).

In Figure 7 and 8, we plot the *inverse* relative price of Machinery and Equipment against foreign supplier access and domestic plus foreign supplier access. Countries located in the upper right of these figures are thus characterised by *low* relative prices of Machinery and Equipment and high levels of supplier access. It is clear that the regression results in Table 10 are not driven by a few influential observations; the change in the position of Australia, New Zealand, Japan, and the United States when one controls for domestic supplier access in Figure 8 is again consistent with our economic priors.

<Figures 7 and 8 about here>

8. Economic Structure and Policy Analysis

The estimates of the trade equation that we have used so far are based on country and partner dummies, which have the advantage of capturing relevant country characteristics that are not directly observable, but are nevertheless revealed through trade performance. For example, the degree of openness of the country, the numbers of firms, and the values of prices and prices indices within the country (see equations (11), defining market and supply capacity). This section considers the robustness of the results to an alternative econometric specification in which we replace country dummies by economic and geographic variables to model supply capacity, S_s, market capacity, M_r, and those elements of transportation costs that are common across exporting or importing countries. This additional economic structure enables us to investigate the predicted effects of these variables on per capita income.

Thus, in equation (12), supply capacity, S_s, and demand capacity, M_r are modelled using country and partner GDP data (Y_s and Y_r respectively). Trade barriers and transportation costs are captured by dummy variables for whether exporting countries and importing partners are land-locked ($llock_s$ and $llock_r$ respectively), islands (isl_s and isl_r respectively), and pursue open trade policies ($open_s$ and $open_r$ respectively).[20] As before, the country-partner pair specific elements of transportation costs are captured by distance between capital cities ($dist_{sr}$) and a dummy variable for whether or not an exporting country and importing partner share a common border ($bord_{sr}$). The first-stage trade regression becomes,

$$\ln(X_{sr}) = \alpha + \beta\ln(Y_s) + \gamma\ln(Y_r) + \delta_1\ln(dist_{sr}) + \delta_2\ln(bord_{sr}) + \delta_3 isl_s + \delta_4 isl_r + \delta_5 llock_s + \delta_6 llock_r + \delta_7 open_s + \delta_8 open_r + u_{sr}. \tag{22}$$

Column (1) in Table 11 presents the results of estimating the specification above on 1994 data using OLS. All variables are correctly signed according to economic priors and statistically significant at the 5% level. Both a country's own GDP (supply capacity) and its trade partner's GDP (demand capacity) have a positive effect on bilateral trade flows, with a coefficient slightly greater than one. Each of the distance and land-locked variables has a negative effect on international trade, while the common border and island variables have positive effects. We find evidence of a positive relationship between Sachs and Warner (1995)'s trade policy-based measure of international openness and bilateral trade. In column (2) of Table 11, we estimate the same specification for the censored sample, producing similar results. Column (3) explicitly takes into account the truncated nature of the data by using the Tobit estimator. This increases the size of the coefficients on own and partner GDP, and increases the size of the coefficients on the land-locked, island, and openness variables.

Table 11: Trade Equation (Alternative Specification)

$\ln(X_{sr})$	(1)[a],[b]	(2)[a],[b]	(3)[a],[c]
Obs	9506	7637	9506
Year	1994	1994	1994
$\ln(dist_{sr})$	-1.286	-1.096	-1.457
	(0.035)	*(0.026)*	*(0.042)*
$\ln(Y_r)$	1.011	0.923	1.134
	(0.016)	*(0.014)*	*(0.021)*
$\ln(Y_s)$	1.198	1.065	1.336
	(0.017)	*(0.014)*	*(0.021)*
$llock_r$	-0.724	-0.415	-0.997
	(0.078)	*(0.064)*	*(0.090)*
$llock_s$	-0.565	-0.301	-0.858
	(0.075)	*(0.067)*	*(0.090)*
isl_r	0.221	0.025	0.308
	(0.073)	*(0.063)*	*(0.099)*
isl_s	0.255	0.136	0.328
	(0.080)	*(0.061)*	*(0.099)*
$open_r$	1.276	0.676	1.356
	(0.076)	*(0.060)*	*(0.094)*
$open_s$	0.824	0.567	0.848
	(0.077)	*(0.057)*	*(0.094)*
$bord_{sr}$	1.583	1.481	1.574
	(0.217)	*(0.137)*	*(0.212)*
Estimation	OLS	OLS	Tobit
$F(\cdot)$	3529.00	2271.22	-
Prob > F	0.000	0.000	-
R-squared	0.706	0.737	-
Root MSE	2.589	1.852	-
Log Likelihood	-	-	-21146.995
LR $\chi^2(\cdot)$	-	-	10365.82
Prob > χ^2	-	-	0.000
Pseudo R^2	-	-	0.197

Notes: [a] The smaller number of observations than in Table 1 is because the Sachs and Warner (1995) openness variable is unavailable for Panama, Saudi Arabia, and Yemen.
[b] Huber-White heteroscedasticity robust standard errors in parentheses.
[c] 1869 left-censored observations <=0, 7637 uncensored observations.

Predicted values of market access and supplier access are obtained from equation (22) in a manner exactly analogous to that used before,

$$\hat{MA}_s = D\hat{MA}_s + F\hat{MA}_s = (Y_s)^{\hat{\gamma}}(T_{ss})^{1-\sigma} + \sum_{r \neq s} (Y_r)^{\hat{\gamma}}.dist_{sr}^{\hat{\delta}_1}.bord_{sr}^{\hat{\delta}_2}.\Lambda \qquad (23)$$

$$S\hat{A}_r = DS\hat{A}_r + FS\hat{A}_r = (Y_r)^{\hat{\beta}}(T_{rr})^{1-\sigma} + \sum_{s \neq r} (Y_s)^{\hat{\beta}}.dist_{sr}^{\hat{\delta}_1}.bord_{sr}^{\hat{\delta}_2}.\Lambda \qquad (24)$$

$$\Lambda \equiv [\exp(isl_s)]^{\hat{\delta}_3}[\exp(isl_r)]^{\hat{\delta}_4}[\exp(llock_s)]^{\hat{\delta}_5}[\exp(llock_r)]^{\hat{\delta}_6}[\exp(open_s)]^{\hat{\delta}_7}[\exp(open_r)]^{\hat{\delta}_8}$$

Again we use estimates from the Tobit specification of the trade equation, and consider three alternative measures of domestic market access and domestic supplier access. The results of estimating the wage equation with the new predicted values for market and supplier access ($\hat{MA}_s$ and $S\hat{A}_s$) are reported in Table 12. This is analogous to Table 8 in the previous section, except that we use 1996 data on GDP per capita to proxy for manufacturing wages.

In column (1), we regress GDP per capita on predicted *foreign* market access. The estimated coefficient is positive and statistically significant at the 5% level; the model explains approximately 57% of the cross-country variation in per capita income. In column (2), we include information on total market access (foreign plus domestic), using our preferred measure of domestic market access (MA(3)). The estimated coefficient is again positive and statistically significant at the 5% level, and the R^2 of the regression rises to 0.74. Column (3) presents the results using supplier access (foreign plus domestic), while columns (4) - (6) include information on both market and supplier access and exploit the theoretical restriction on the relative magnitude of the estimated coefficients. The estimated coefficient on supplier access ranges from 0.16 to 0.20 (implying an estimated coefficient on market access between 0.3 and 0.34) and is statistically significant at the 5% level. The model explains over 70% of the cross-country variation in per capita income.

Table 12: Market access, supplier access and income per capita[a]

ln*(Manufacturing wage per worker)*	(1)[b]	(2)[b]	(3)[b]	(4)[b]	(5)[b]	(6)[b]
Obs	98	98	98	98	98	98
Year	1996	1996	1996	1996	1996	1996
α	-	-	-	0.4	0.5	0.6
σ				6	8	10
$ln(FMA_s)$	0.556	-	-	-	-	-
	[0.057]					
$\ln(MA_s) = \ln(DMA_s(3)+FMA_s)$	-	0.525	-	0.342	0.325	0.300
		[0.034]				
$\ln(SA_r) = \ln(DSA_r(3)+FSA_r)$	-	-	0.469	0.164	0.179	0.201
			[0.048]	*[0.015]*	*[0.017]*	*[0.019]*
Estimation	OLS	OLS	OLS	OLS	OLS	OLS
R^2	0.565	0.744	0.575	0.738	0.737	0.736
$F(\cdot)$	141.03	315.79	269.25	299.17	297.68	295.44
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000

Notes: [a] first stage estimation of the trade equation using Tobit (column (3) in Table 11).
[b] Bootstrapped standard errors in square parentheses (200 replications).

The parameter estimates reported in Table 11 may be used to evaluate the effect of each variable included in the trade equation (eg whether a country is land-locked or not, whether a country pursues open trade policies) on market and supplier access. Combining this information with the estimated coefficients on market and supplier access from Table 12, one obtains the effect of each variable on predicted income per capita. Table 13 reports the results of undertaking such an analysis for the land-locked, island, openness, and distance variables. Seven countries are considered. Three of these are islands, at varying stages of economic development: Australia, Madagascar, and Mauritius. Four of the countries are land-locked, and five are, to some degree, closed on the Sachs and Warner (1995) definition of international openness.

First, we evaluate the effect of each variable on predicted income per capita through *foreign* market access (FMA), for which we use the parameter estimates in column (1) of Table 12. Second, we consider the total effect of each variable on predicted income per capita through both market and supplier access (domestic plus foreign (MA and SA)), for which we use the parameter estimates in column (6) of Table 12. From equation (23), foreign market access for country *s* may be written as follows,

$$FMA_s = [\exp(isl_s)]^{\hat{\delta}_3} \exp[(llock_s)]^{\hat{\delta}_5} [\exp(open_s)]^{\hat{\delta}_7} . \sum_r [\exp(isl_r)]^{\hat{\delta}_4} [\exp(llock_r)]^{\hat{\delta}_6} [\exp(open_r)]^{\hat{\delta}_8} dist_{sr}^{\hat{\delta}_1} bord_{sr}^{\hat{\delta}_2} (Y_r)^{\hat{\gamma}} \qquad (25)$$

Column (1) of Table 13 evaluates the effect of being land-locked on per capita income in the Central African Republic, Hungary, Paraguay, and Zimbabwe. We find that gaining a coastline raises a country's predicted income per capita from FMA by 61%.[21] Loss of island status has a more modest effect, and reduces predicted income per capita from FMA by 17%.[22] The effect of open trade policies is of a similar size to gaining a coastline - predicted income per capita from FMA rises by 60%.

Since $MA_s = DMA_s + FMA_s$ and $SA_s = DSA_s + FSA_s$, the full impact of each variable on predicted income per capita (through domestic plus foreign market and supplier access) depends upon the relative importance of the domestic market and domestic sources of supply. Thus, we find that island status has a very small effect on predicted income per capita in Australia, a developed country with a large domestic market, and a much larger effect in Mauritius. The full effect of a variable on predicted income per capita may clearly exceed the effect from FMA alone. This will be more likely to occur in countries where domestic market and supplier access are relatively unimportant. Thus, giving the Central African Republic access to a coastline raises its predicted income from MA and SA by 64% compared to an effect of 61% from FMA alone.

Table 13: Economic Magnitudes

Country		Variable				
		(1) Access to Coast	(2) Loss of Island Status	(3) Become Open[(a)]	(4) Distance (50% closer to all partners)	(5) Distance (Central Europe)
Australia	FMA	-	-17%	-	75%	-
	MA&SA		-2%		13%	
Central African Republic	FMA	61%	-	60%	75%	199%
	MA&SA	64%		75%	73%	191%
Hungary	FMA	61%	-	57%	75%	-
	MA&SA	29%		33%	33%	
Mauritius	FMA	-	-17%	-	75%	287%
	MA&SA		-11%		54%	212%
Madagascar	FMA	-	-17%	60%	75%	282%
	MA&SA		-14%	71%	69%	258%
Paraguay	FMA	61%	-	55%	75%	177%
	MA&SA	39%		43%	45%	105%
Zimbabwe	FMA	61%	-	60%	75%	266%
	MA&SA	32%		39%	36%	141%

Notes: [(a)] actual values for the Sachs and Warner (1995) openness index are 1 in Australia, 0 in Central African Republic, 0.038 in Hungary, 1 in Mauritius, 0.077 in Paraguay, and 0 in Zimbabwe.

Table 14: The Effect of Removing a Common Border

Removal of Common Border	Effect on Per Capita Income	
Germany - Czech Republic	Germany	Czech Republic
FMA	-0.18%	-50%
MA&SA	-0.02%	-39%
U.S. - Mexico	U.S.	Mexico
FMA	-1.1%	-52%
MA&SA	-0.02%	-9%
Central Afr. Republic - Chad	Central Afr. Republic	Chad
FMA	-0.01%	-0.005%
MA&SA	-0.01%	-0.003%

Column (4) of Table 13 evaluate the effect of halving a country's distance from all of its trade partners. Predicted income per capita from FMA rises by 75%. The effect on predicted income per capita from MA and SA again depends on the relative importance of domestic market and supplier access, and varies from 13% in Australia to 73% in the Central African Republic. This suggests a substantial effect of distance on income per capita. The proportional amount of variation in distance in this experiment (a 50% decrease) is smaller than that implied in the analysis of the effects of being land-locked or pursuing open trade policies. To obtain a further feel for the quantitative importance of distance, column (5) of Table 13 considers the effect on market and supplier access of moving the four developing countries located far from centres of world economic activity (Central African Republic, Madagascar, Mauritius, Paraguay, and Zimbabwe) to central Europe. Specifically, we replace the distance vector for each of these countries by that for Hungary. Predicted income per capita from FMA rises by 287% in Mauritius; the full effect on predicted income per capita again varies with the relative importance of domestic market and supplier access (from 105% in Paraguay to 258% in Madagascar). This emphasises the economic advantages conveyed to the transition economies of Central and Eastern Europe by their location on the edge of high income Western Europe.

The estimated coefficient on distance in Table 11 may be used to evaluate foreign market access across the globe. We divide the world into a discrete grid, with each grid point separated by 2.5 degrees of latitude and 2.5 degrees of longitude. A grid point's FMA depends on its distance from all 101 countries in our dataset, and is evaluated using the formula: $FMA_s = \sum_r (dist_{sr})^{-1.475}.(Y_r)^{1.134}$. Figure 9 graphs the resulting three-dimensional surface of log FMA across the world.[23] The concentration of FMA over North America, Western Europe, and Japan is immediately evident. The decrease in FMA with distance from these centres of world economic activity is extremely rapid, and the benefits of location on the borders of Europe or in South East Asia close to Japan are shown clearly. The density of FMA is much greater in the Northern hemisphere than the Southern, although smaller concentrations of FMA over South America and over Australia and New Zealand are visible.

<Figure 9 about here>

The importance of geographical proximity is shown again in Table 14, which uses the estimated coefficients in Tables 11 and 12 to examine the effects of a common border. The common borders between Germany and the Czech Republic and the United States and Mexico have substantial effects on predicted income per capita in the smaller countries. Thus, removing the common border gives a fall in predicted income per capita in the Czech Republic ranging from 50% (FMA alone) to 39% (with the full effect of the decrease in MA and SA). The effects on Mexico of the elimination of the USA-Mexico common border are smaller, reflecting the greater relative importance of domestic market and supplier access. Predicted income per capita from FMA falls by 52%, but the full effect of the decrease in MA and SA is to reduce Mexican income per capita by 10%. The elimination of a common border between low income developing countries that trade very little with one-another, such as the Central African Republic and Chad, is very much smaller. Chad's predicted income per capita from FMA and from MA plus SA falls by 0.02%. This suggests that the effects of closer regional integration between low income developing countries may be relatively small compared to the gains to be had from closer integration with high income developed countries.

9. Conclusions

Cross-country differences in income per capita and manufacturing wages are enormous – in 1996, manufacturing wages at the 90th percentile were approximately fifty times greater than those at the 10th percentile. These differences have not been bid away by the mobility of manufacturing firms and plants. There are many reasons for the reluctance of firms to move production to low wage locations, one of which is the distance of these locations from markets and suppliers.

This paper has examined how much of the cross-country variation in income per capita and manufacturing wages can be explained simply by countries' location relative to their markets and to their suppliers. In a standard theoretical model of economic geography the value of bilateral exports, the manufacturing wage, and the relative price of manufacturing goods are determined by location relative to sources of demand and supply. Estimates based on bilateral trade flows provide measures of market and supplier access for each country, which in turn determine the wage that manufacturing firms can afford to pay. These measures were found to explain approximately 70% of the cross-country variation in income per capita and 50% of the variation in manufacturing wages. As predicted by the theoretical model, the relative price of manufacturing goods was shown to be negatively and statistically significantly related to a country's supplier access. These results were shown to robust to inclusion of further explanatory variables, across a number of different econometric specifications, and to the use of alternative measures of the manufacturing wage.

Our results may seem rather pessimistic for developing countries, suggesting that even if tariff and institutional obstacles to trade and investment are removed the penalty of distance will continue to hold down the incomes of remote regions. However, it is important to recall that our results are derived for a given location of production and expenditure. As new markets and centres of manufacturing activity emerge, so the market and supplier access of neighbouring countries improves. Our results point to the importance of understanding the role of geography in shaping the evolution of the cross-country distribution of income.

Appendix A: Data

Bilateral Trade: data on bilateral trade flows are from the World Bank COMTRADE database. This provides information for the 101 countries listed in Table A1 during 1992-6.

GDP per capita: data on current price (US dollars) GDP and on population are from the World Bank. These data are also available for the 101 countries listed in Table A1 during 1992-6.

Geographical variables: data on bilateral distance, internal area, existence of a common border, and whether a country is an island or land-locked are from the World Bank. These data are available for the 101 countries listed in Table A1.

Manufacturing wage per worker: data on number of employees and wages and salaries (current price US dollars) in total manufacturing are from the UNIDO Industrial Statistics Database. Information is available for the 62 countries indicated in Table A1 during 1992-6.

Relative price of machinery and equipment: data on the price of machinery and equipment and GDP in local currency units per US dollar are from Phase V of the United Nations International Comparisons Project (United Nations (1994)). The data are available for the 46 countries indicated in Table A1 and are for 1985.

Physical Geography and Institutional, Social, and Political Characteristics: data on hydrocarbons per capita, fraction of land area in the geographical tropics, prevalence of Malaria, socialist rule, and the occurrence of an external war are from Gallup, Sachs, and Mellinger (1998). Information is available for all 101 countries in our dataset, except for the data on hydrocarbons per capita which are unavailable for Moldova and Yemen. The data can be downloaded from http://www2.cid.harvard.edu/ciddata.

Social Infrastructure: data on distance from the equator, the fraction of the population speaking English, and the fraction of the population speaking a European language are from Hall and Jones (1998). Information is available for 86 of the countries listed in Table A1. Data are unavailable for the following countries: Albania, Armenia, Czech Republic, Estonia, United Germany, Croatia, Kazhakhstan, Kyrgyz Republic, Lithuania, Latvia, Moldova, Macedonia, Russia, Slovak Republic, and Slovenia. The data can be downloaded from: http://www.stanford.edu/~chadj/datasets.html.

International Openness: data on international openness are from Sachs and Warner (1995). Information is available for 98 of the countries listed in Table A1. The countries for which data are unavailable are Panama, Saudi Arabia, and Yemen. The data can be downloaded from http://www2.cid.harvard.edu/ciddata.

Africa: Algeria, Central African Republic, Cote d'Ivoire, Cameroon, Congo Republic, Egypt, Ethiopia, Gabon, Kenya, Madagascar, Mozambique, Mauritius, Malawi, Morocco, Sudan, Senegal, Chad, Tanzania, Tunisia, South Africa, Zambia, and Zimbabwe.

Latin America and the Caribbean: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Peru, Paraguay, El Salvador, Trinidad and Tobago, Uruguay, and Venezuela.

South East Asia: China, Hong Kong, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Thailand, and Taiwan.

Other Asia: Bangladesh, India, Sri Lanka, Mongolia, Nepal, and Pakistan.

Eastern Europe and the former USSR: Albania, Armenia, Bulgaria, Czech Republic, Estonia, Croatia, Hungary, Kazakhstan, Kyrgyz Republic, Lithuania, Latvia, Moldova, Macedonia, Poland, Romania, Russia, Slovak Republic, and Slovenia.

Middle-East: Israel, Jordan, Saudi Arabia, Syria, and Yemen.

Table A1: country composition and availability of wage / machinery and equipment relative price data

1. Albania (ALB)	(w)		28. Estonia (EST)		
2. Argentina (ARG)	(w)		29. Ethiopia (ETH)	(w)	(g)
3. Armenia (ARM)			30. Finland (FIN)	(w)	(g)
4. Australia (AUS)		(g)	31. France (FRA)	(w)	(g)
5. Austria (AUT)	(w)	(g)	32. Gabon (GAB)	(w)	
6. Bangladesh (BGD)	(w)	(g)	33. UK (GBR)	(w)	(g)
7. Bulgaria (BGR)			34. Greece (GRC)		(g)
8. Belg./Lux (BLX)	(w)	(g)	35. Guatemala (GTM)		
9. Bolivia (BOL)	(w)		36. Hong Kong (HKG)	(w)	(g)
10. Brazil (BRA)	(w)		37. Honduras (HND)		
11. C Afr. Rp. (CAF)	(w)		38. Croatia (HRV)	(w)	
12. Canada (CAN)	(w)	(g)	39. Hungary (HUN)	(w)	(g)
13. Switzerl. (CHE),			40. Indonesia (IDN)	(w)	
14. Chile (CHL)	(w)		41. India (IND)	(w)	(g)
15. China (CHN)			42. Ireland (IRL)	(w)	(g)
16. Cote d'Ivoire (CIV)		(g)	43. Israel (ISR)	(w)	
17. Cameroon (CMR)	(w)	(g)	44. Italy (ITA)	(w)	(g)
18. Congo Rep. (COG)		(g)	45. Jamaica (JAM)	(w)	
19. Colombia (COL)	(w)		46. Jordan (JOR)	(w)	
20. Costa Rica (CRI)	(w)		47. Japan (JPN)		(g)
21. Czech Rep. (CZE)			48. Kazakhstan (KAZ)		
22. Germany (DEU)		(g)	49. Kenya (KEN)	(w)	(g)
23. Denmark (DNK)	(w)	(g)	50. Kyrgyz Rp. (KGZ)		
24. Algeria (DZA)	(w)		51. Korea, Rp. (KOR)	(w)	(g)
25. Ecuador (ECU)	(w)		52. Sri Lanka (LKA)		(g)
26. Egypt (EGY)		(g)	53. Lithuania (LTU)	(w)	
27. Spain (ESP)	(w)	(g)	54. Latvia (LVA)		

Notes: (w) indicates that data on manufacturing wages per worker are available; (g) indicates that data on the relative price of machinery and equipment are available

Table A1 (cont): country composition and availability of wage / machinery and equipment relative price data

55. Morocco (MAR)	(w)	(g)	82. Singapore (SGP)		
56. Moldova (MDA)			83. El Salvador (SLV)		
57. Madagasc. (MDG)		(g)	84. Slovak Rep. (SVK)		
58. Mexico (MEX)	(w)		85. Slovenia (SVN)	(w)	
59. Macedonia (MKD)	(w)		86. Sweden (SWE)	(w)	(g)
60. Mongolia (MNG)			87. Syria (SYR)		
61. Mozambiq. (MOZ)	(w)		88. Chad (TCD)		
62. Mauritius (MUS)	(w)	(g)	89. Thailand (THA)	(w)	(g)
63. Malawi (MWI)	(w)	(g)	90. Trinidad/T. (TTO)	(w)	
64. Malaysia (MYS)	(w)		91. Tunisia (TUN)	(w)	(g)
65. Nicaragua (NIC)			92. Turkey (TUR)	(w)	(g)
66. Netherlands (NLD)	(w)	(g)	93. Taiwan (TWN)	(w)	
67. Norway (NOR)	(w)	(g)	94. Tanzania (TZA)	(w)	(g)
68. Nepal (NPL)	(w)		95.Uruguay (URY)		
69. New Zeal. (NZL)	(w)	(g)	96. USA (USA)	(w)	(g)
70. Pakistan (PAK)	(w)	(g)	97. Venezuela (VEN)	(w)	
71. Panama (PAN)			98. Yemen (YEM)		
72. Peru (PER)			99. South Afr. (ZAF)	(w)	
73. Philippines (PHL)	(w)	(g)	100. Zambia (ZMB)	(w)	(g)
74.Poland (POL)		(g)	101. Zimbabwe (ZWE)	(w)	(g)
75. Portugal (PRT)		(g)			
76. Paraguay (PRY)					
77. Romania (ROM)	(w)				
78. Russia (RUS)					
79. Saudi Arab. (SAU)					
80. Sudan (SDN)					
81. Senegal (SEN)		(g)			

Notes: (w) indicates that data on manufacturing wages per worker are available; (g) indicates that data on the relative price of machinery and equipment are available

Endnotes:

1. Radelet and Sachs (1999) draw attention to way in which transport costs which are small as a share of the value of gross output can have a very large effect on value added. Estimates of actual transport costs for landlocked countries can exceed 30%, see Radelet and Sachs (1999) and Limao and Venables (1999).

2. The exposition follows Fujita, Krugman, and Venables (1999), Chapter 14. See also Krugman and Venables (1995).

3. The full general equilibrium model consists of an agricultural and manufacturing sector. Manufacturing can be interpreted as a composite of manufacturing and service activities. See Fujita, Krugman, and Venables (1999), Chapter 14 for further details.

4. The transport cost term enters with exponent $1 - \sigma$ not $- \sigma$; because total shipments to market r are T_{sr} times quantities consumed.

5. Hanson (1997) directly estimates a labour demand equation derived from Krugman (1991) using US county-level data. In Krugman (1991), labour mobility plays an important role in explaining the agglomeration of economic activity. While labour mobility is likely to be high across US counties, it is likely to be low across the developed and developing countries in our sample. The model of Fujita, Krugman, and Venables (1999) considered here explains the location of economic activity in space in terms of input-output linkages. The availability of data on bilateral international trade flows and the price of manufacturing goods at the country-level enables us to exploit the model's predictions for international trade and relative prices. We use the trade equation to obtain estimates of unobserved market access and use these to explain the cross-country distribution of manufacturing wages.

6. This specification is consistent with the empirical literature on gravity models: see, for example, Anderson (1979) and Wang and Winters (1991).

7. The COMTRADE database records the values of bilateral trade flows to a high degree of accuracy; these zeros are genuine zeros rather than missing values.

8. The minimum bilateral distance between any two trade partners in our data set is 42km. The large negative effect of national borders on trade flows is well-documented; for example, McCallum (1995) finds that, other things equal, trade between two Canadian provinces is more than 20 times larger than trade between a province and a US state.

9. Note that, even in the absence of exogenous technology differences, measured aggregate productivity may vary substantially across countries due to differences in the transport cost inclusive price of manufacturing inputs and output. In order to arrive at a 'true' measures of aggregate Total Factor Productivity (TFP), one must embrace a multi-sector model with intermediate inputs and obtain disaggregated data on the transport cost inclusive price of manufacturing goods. See Redding and Venables (2000).

10. Each bootstrap replication re-samples the 10100 country-partner observations in the dataset, estimates the first-stage trade regression, generates predicted values for market and supplier access, and estimates the second-stage wage equation. The conventional number of bootstrap

replications used to estimate a standard error is 50-200 (Efron and Tibsharini (1993)). The standard errors reported in the paper are based on 200 bootstrap replications.

11. Since all data are in current price US$ the move from 1994 to 1996 $ prices is captured in the constant ζ of the wage equation.

12. Weak exogeneity would be violated if agents were able to systematically predict future shocks to manufacturing wages and had an economic incentive to change bilateral trade flows two years prior to a shock. Given a positive discount rate, substantial costs to holding inventories, and the literature on the option value of waiting to invest, it is hard to believe that such effect would be large. We experiment with estimating the trade equation in other years prior to 1994; this yields very similar results.

13. Data on hydrocarbons per capita are unavailable for Moldova and Yemen. See Appendix A for further details concerning the data used.

14. Hall and Jones (1998) also consider the Frankel and Romer (1999) predicted trade share as an ultimate determinant of social infrastructure. This predicted trade share is derived from the estimation of a gravity equation including geographical variables. Information concerning geography's effect on access to markets and sources of supply is already incorporated into our theory-consistent measures of market and supplier access.

15. See Appendix A for further details concerning the data used.

16. Important markets and sources of supply located far from the equator include Canada, USA, Western Europe, and Japan in the Northern Hemisphere, and Australia, New Zealand, and South Africa in the Southern Hemisphere.

17. The countries included in these economic regions are listed in Appendix A.

18. The correlation coefficient between our preferred measures of market and supplier access (MA(3) and SA(3)) is 0.88.

19. In the theoretical model, the manufacturing price index, G_r, is important because it influences unit production costs through the input-output linkages in the manufacturing sector. The analysis provides an alternative explanation for the importance of the relative price of Machinery and Equipment (an empirical proxy for G_r) to that in the literature on equipment investment and growth (eg De Long and Summers (1991)) and the literature on trade in capital goods and knowledge spillovers (eg Eaton and Kortum (2000)).

20. We employ the Sachs and Warner (1995) measure of international openness. This is based on tariff barriers, non-tariff barriers, the black market exchange premium, the presence of a state monopoly on major exports, and the existence of a socialist economic system. See Sachs and Warner (1995) for further details.

21. Limao and Venables (1999) directly estimate the effect of being landlocked on transport costs. The median landlocked country is found to have transport costs 58% higher than the median coastal country.

22. Predicted income per capita is $0.83 = 1.61^{(0.328/-0.858)}$ times what it would be if the country were an island, where 0.328 is the coefficient on the island dummy in Table 11.

23. The distance variable is defined between capital cities. In order to avoid the discreteness introduced by market capacity being evaluated at capital cities, the measure of FMA shown in Figure 9 is smoothed.

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Figure 1 : GDP per capita and FMA

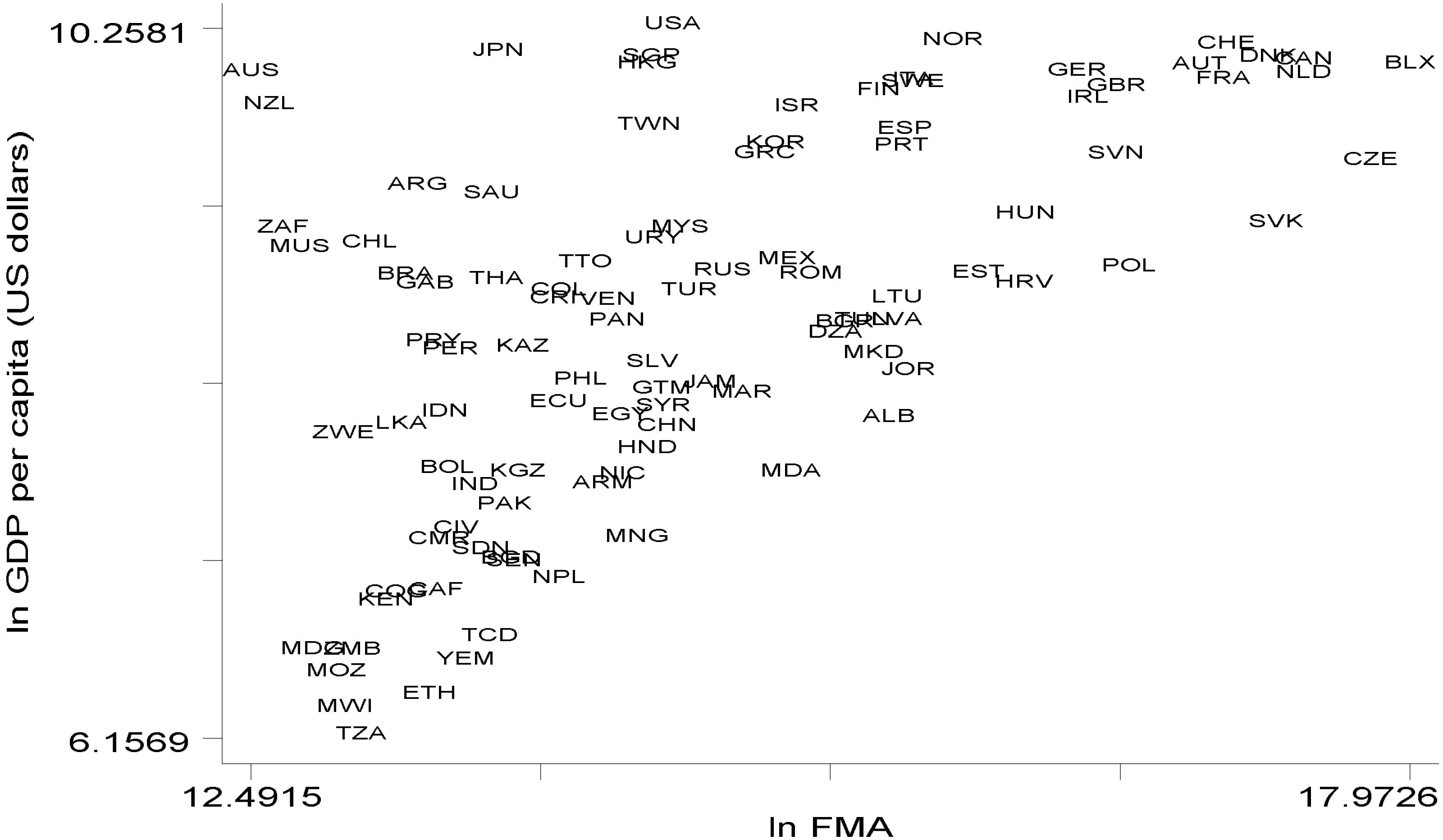

Figure 2 : GDP per capita and MA = DMA(1) + FMA

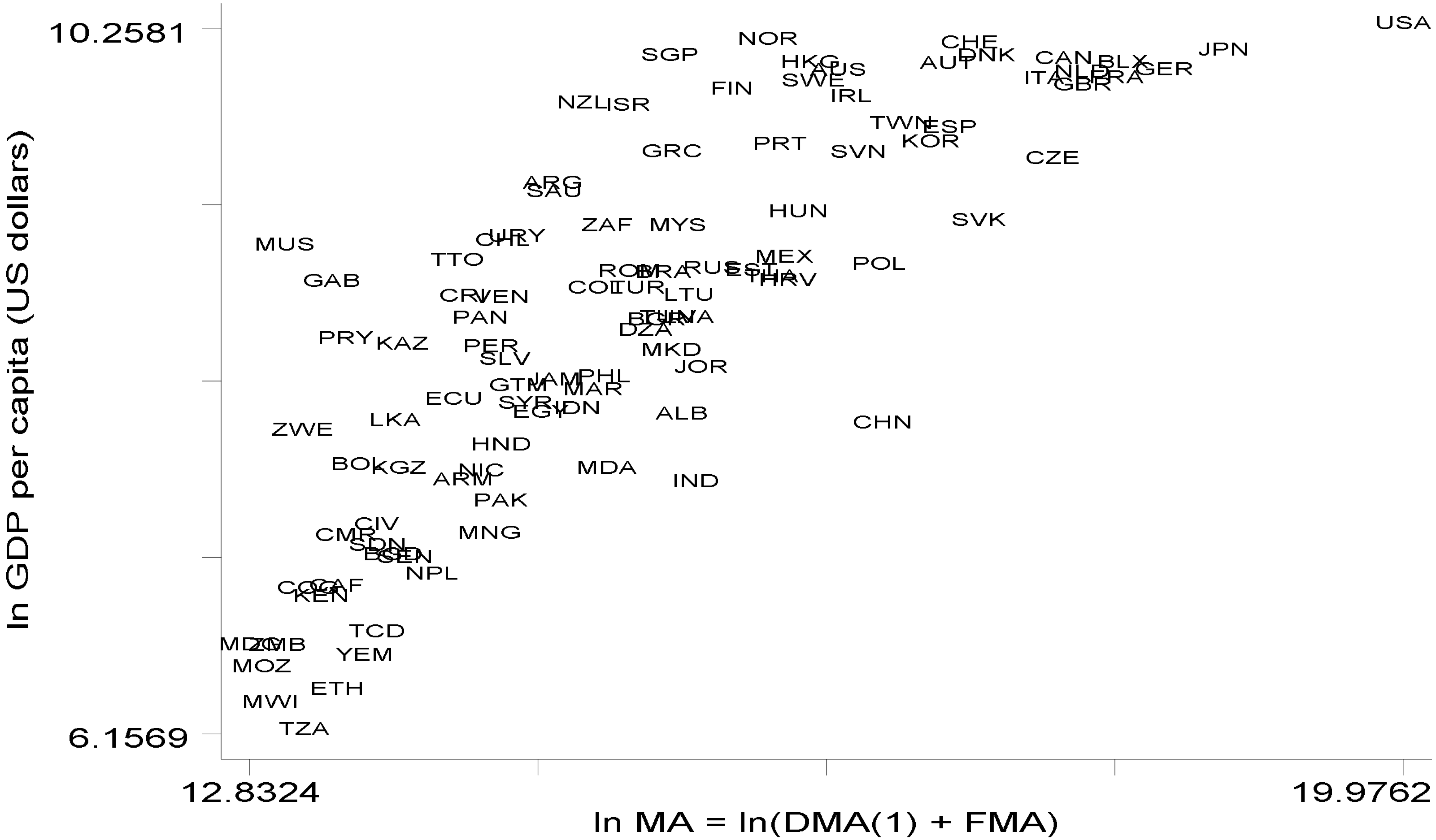

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Figure 3 : GDP per capita and MA = DMA(2) + FMA

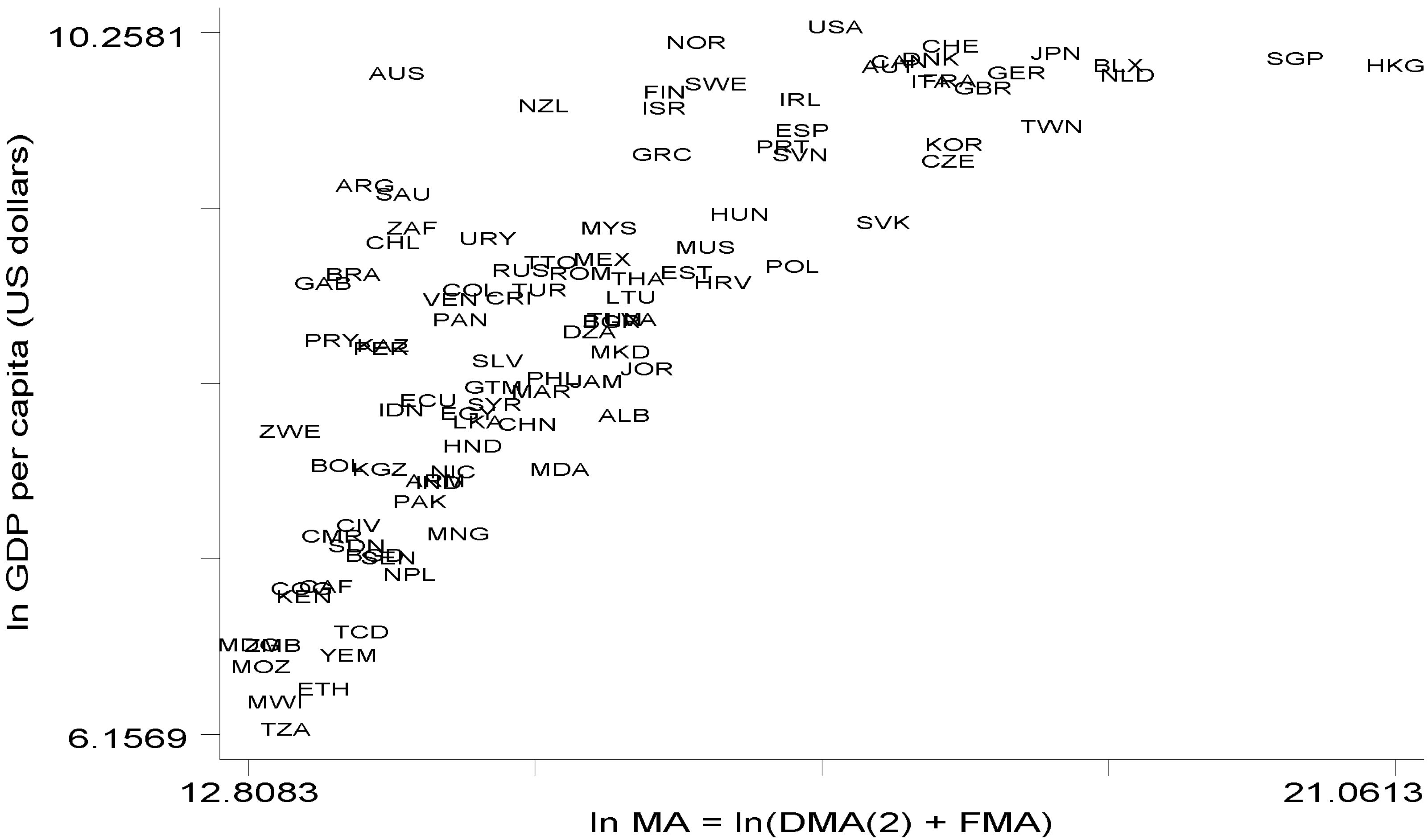

Figure 4 : GDP per capita and MA = DMA(3) + FMA

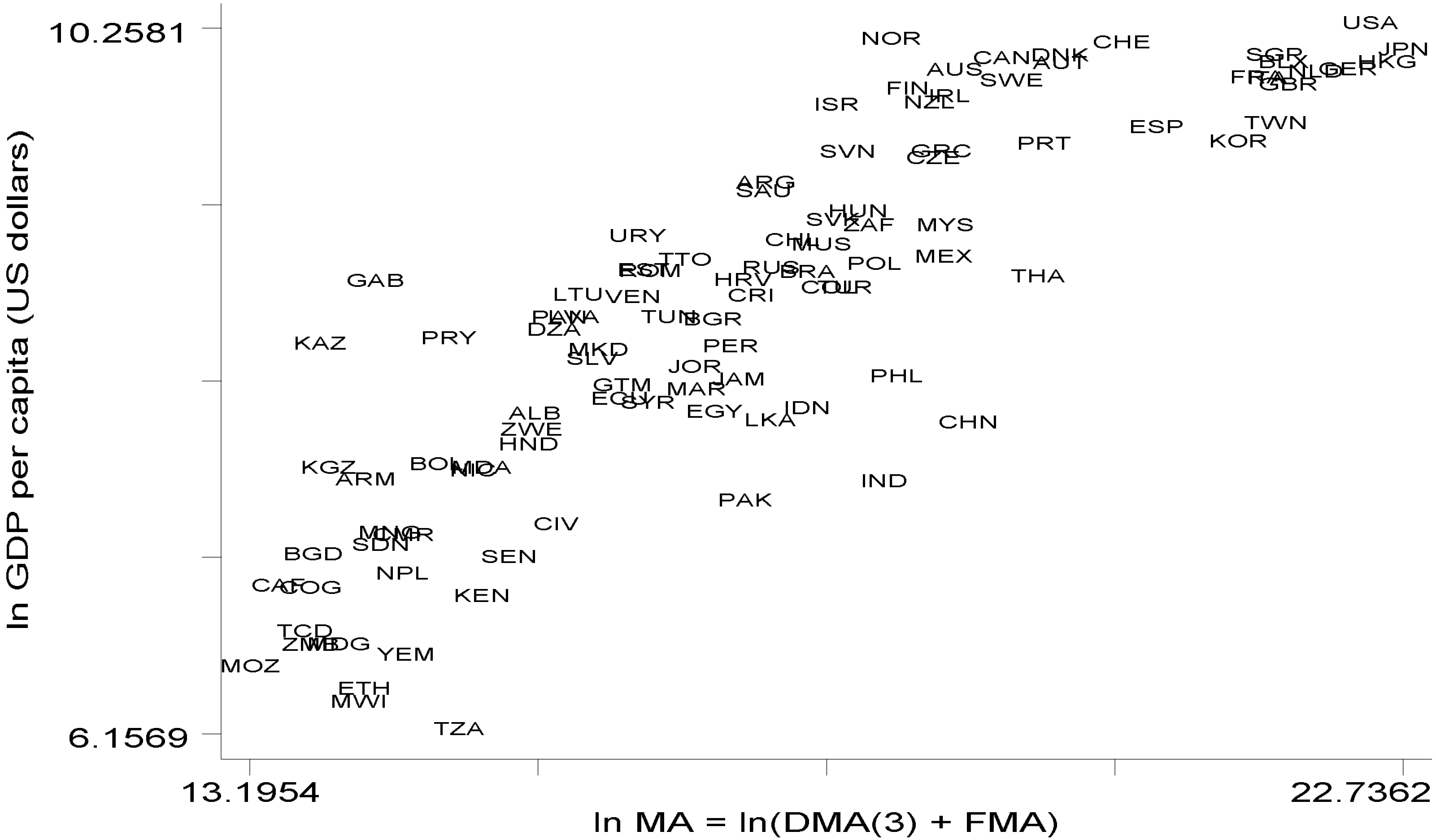

Figure 5 : manufact. wage per worker and FMA

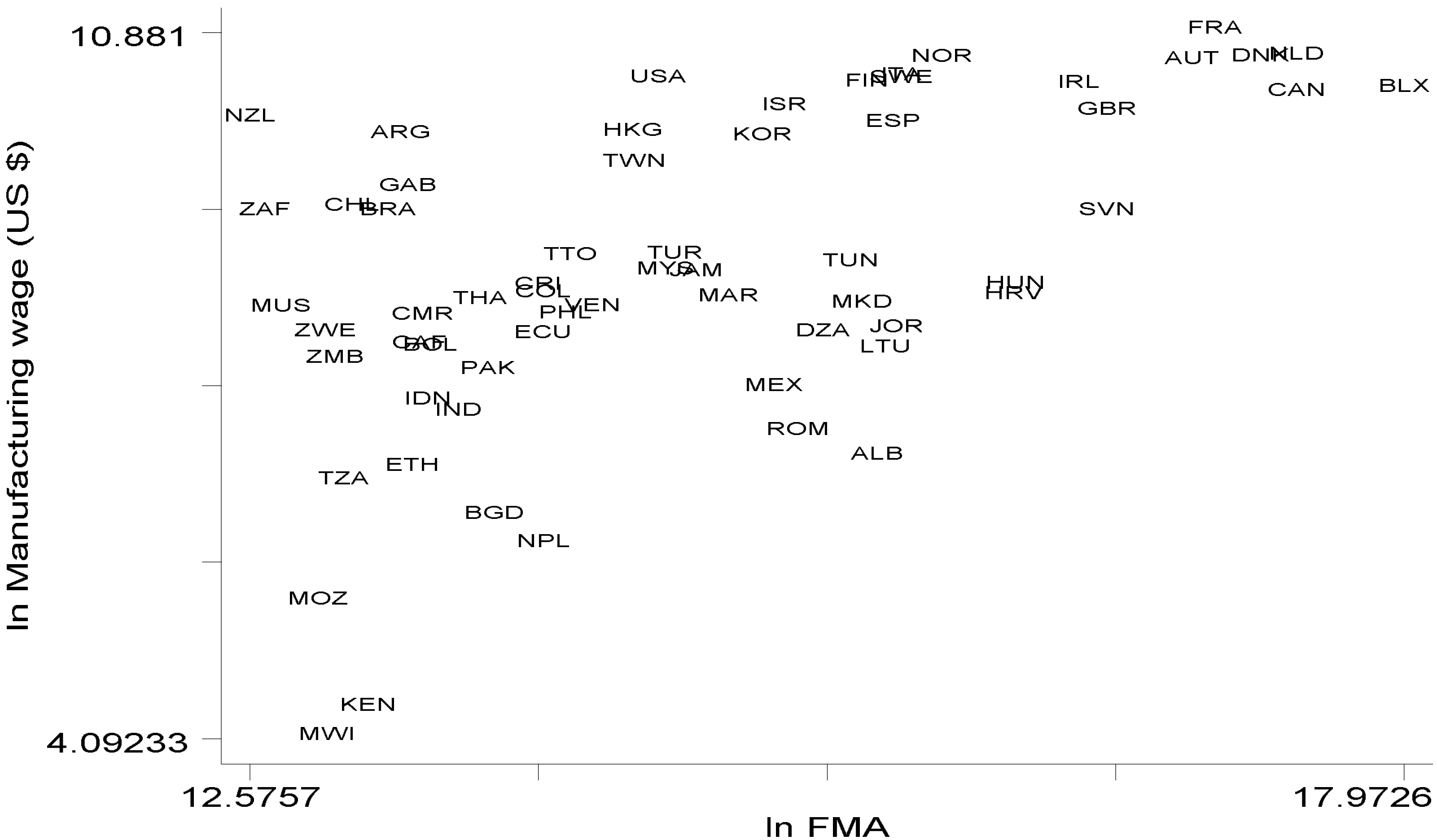

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Figure 6 : manufact. wage per Worker and MA = DMA(3) + FMA

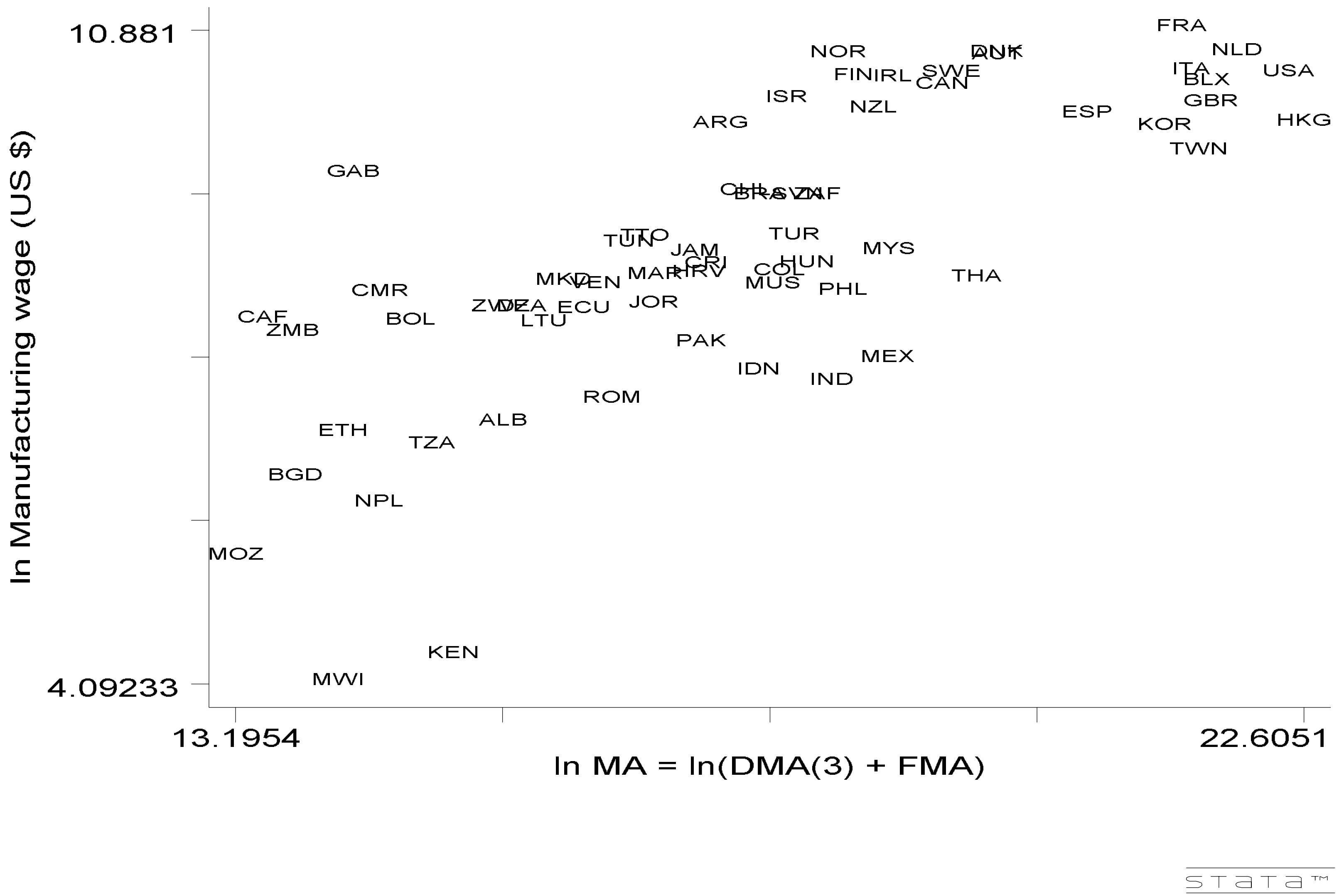


Figure 7 : 1 / Manufacturing Relative Price and FSA

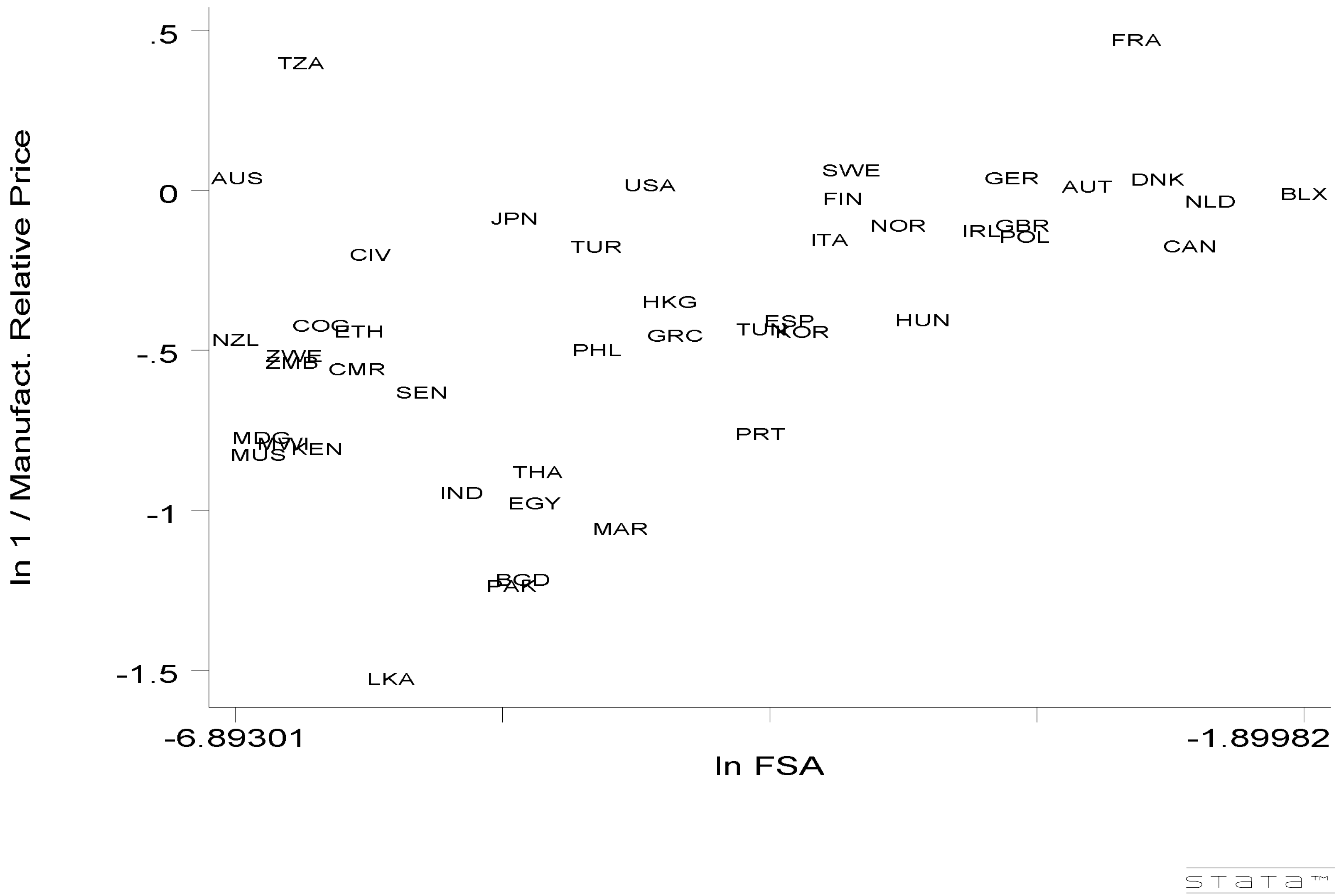
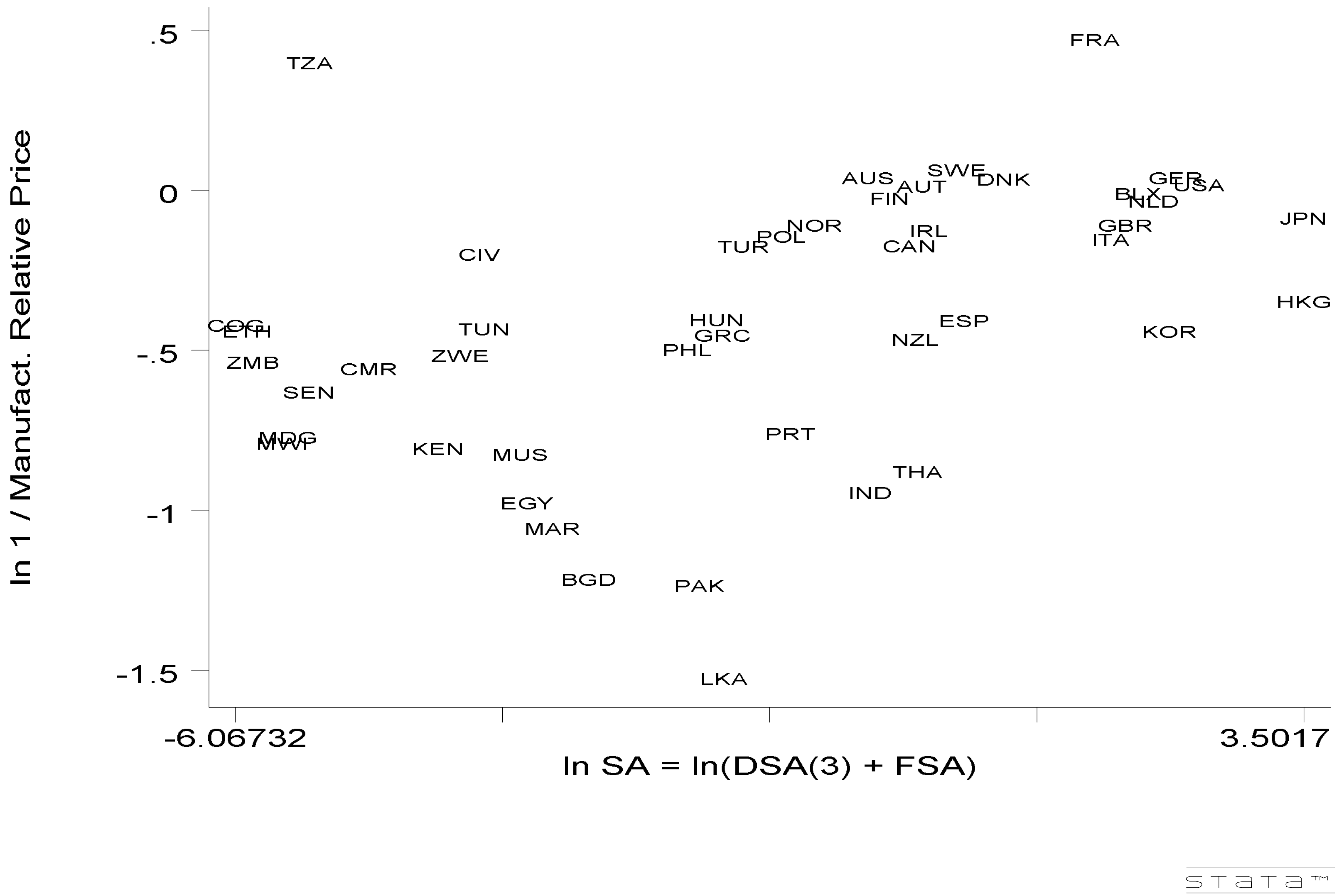


Figure 8 : 1 / Manufacturing Relative Price and SA



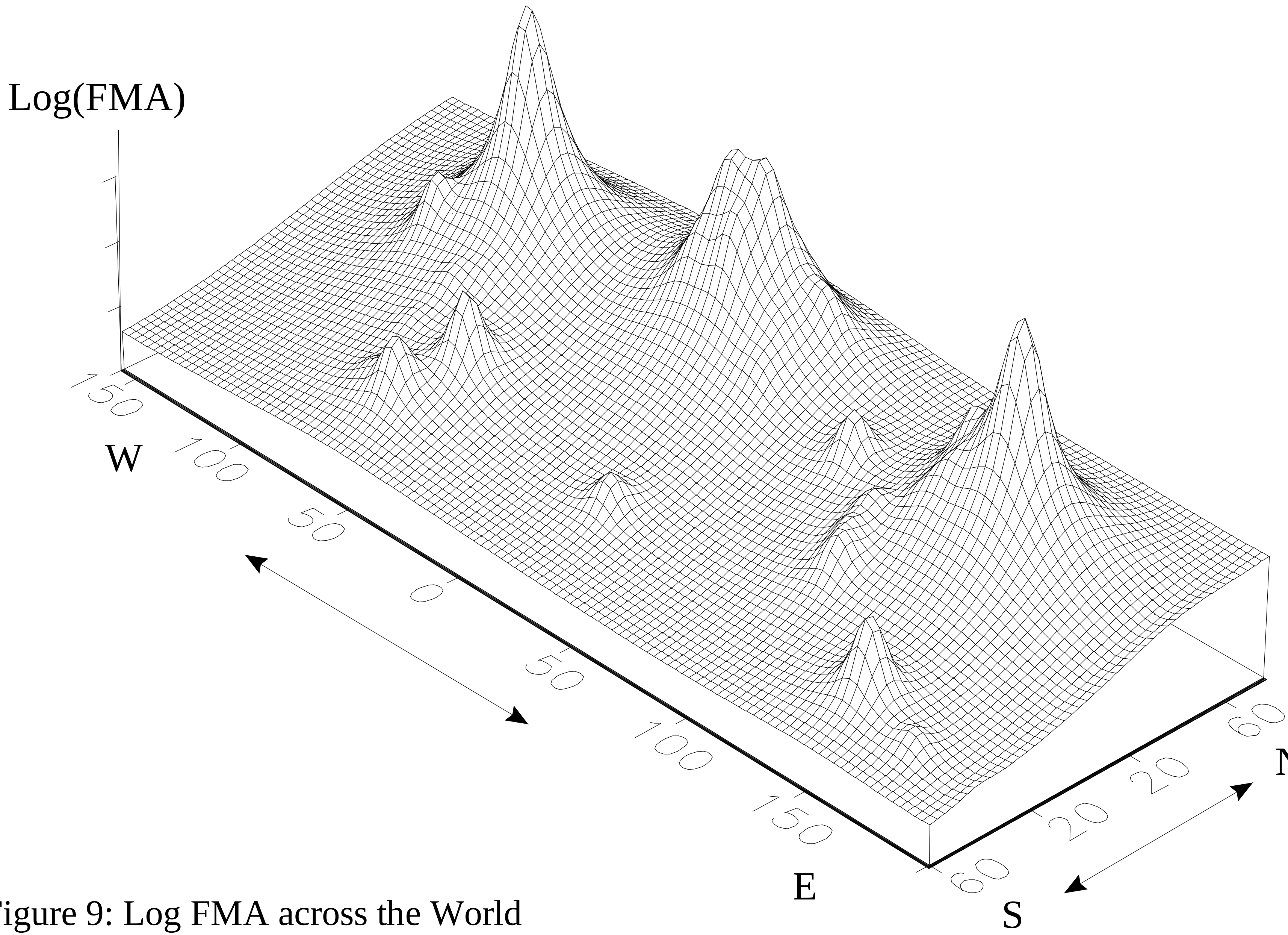


Figure 9: Log FMA across the World