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Spatial income inequality

Stephen Redding*

Summary

■ This paper surveys the empirical economic geography literature concerned with spatial variation in factor incomes. Transport costs and other trade frictions mean that firms in peripheral locations suffer a market access penalty on their sales and face additional costs on imported inputs. As a consequence, firms in these countries can only afford to pay relatively low incomes to immobile factors—even if, for example, their technologies and the institutional framework within which they operate are the same as elsewhere. A wide range of studies exploiting international data, intra-national data, or natural experiments provide evidence of how the geography of access to markets and sources of supply shapes spatial income inequality. ■

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Manufacturing wages vary substantially across geographic space, both within and across countries. In 1996, manufacturing wages at the 90th percentile of the cross-country distribution were more than fifty times higher than those at the 10th percentile. Equally dramatic variation is observed within countries, as is evident from the vast regional disparities in income observed for example within China or India.

There are a number of reasons why factor incomes may vary spatially. These include differences in institutions which affect incentives to innovate and invest (see for example Acemoglu et al., 2001). They also include considerations of first-nature geography—the physical geography of resource endowments, climate and the topography of mountains rivers and coasts (see for example Gallup et al., 1998). More recently, a body of research has documented the importance of second-nature geography—the location of economic agents relative to one another in space—in shaping how well off they are, the economic activities that they undertake and the extent to which they trade.

Second-nature geography may affect factor incomes in a number of ways through its influence on flows of goods, factors of production and ideas. In this paper, I concentrate largely on two mechanisms which are placed centre stage in the theoretical literature on new economic geography. 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 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 rela-

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tively low wages—even if, for example, their technologies and the institutional framework within which they operate are the same as elsewhere.

The potential magnitude of these effects is large. Consider an example where prices of output and intermediate goods are set on world markets, transport costs are borne by the producing country, and intermediates account for 50 per cent of costs. Ad valorem transport costs of 10 per cent on both final output and intermediate goods have the effect of reducing domestic value added by 30 per cent (compared to a country facing zero transport costs), the reduction in value added rising to 60 per cent for transport costs of 20 per cent, and to 90 per cent for transport costs of 30 per cent.[1] Transport costs of this size are in line with recent empirical evidence. For example, based on customs data, Hummels (1999) finds that average expenditure on freight and insurance as a proportion of the value of manufacturing imports is 10.3 per cent in US, 15.5 per cent in Argentina, and 17.7 per cent in Brazil. Limao and Venables (2001) relate transport costs to features of economic geography finding, for example, that the median landlocked country's shipping costs are more than 50 per cent higher than those of the median coastal country. Each of these papers focuses on transport costs narrowly defined (pure costs of freight and insurance) and may understate the true magnitude of barriers to trade if there are other costs to transacting at a distance, such as costs of information acquisition and of time in transit.

This paper summarizes recent empirical work which has sought to estimate the effect of location relative to markets and sources of supply on factor incomes. The analysis begins in Section 1 with a review of the theoretical mechanisms emphasized in the new economic geography literature. Section 2 surveys the international evidence. Section 3 examines the intra-national evidence. Section 4 turns to consider a few studies that have sought to exploit natural experiments to shed light on how economic geography shapes the spatial income inequality. Section 5 concludes.

1. Theoretical background

The theoretical background is provided by new economic geography models incorporating trade costs and increasing returns to scale (see for example Krugman, 1991; Krugman and Venables, 1995; Venables,

[1] See also Radelet and Sachs (1998).

1996; Helpman, 1998; Fujita et al., 1999; and Baldwin et al., 2003). In this section, we sketch the outlines of this general class of models, and draw out their implications for spatial income inequality.[2]

The world consists of a number of locations $i = 1,...R$. The demand-side of the model includes a manufacturing sector where firms produce differentiated varieties, which are typically modelled using the Dixit-Stiglitz Constant Elasticity of Substitution (CES) demand system. Manufacturing varieties are tradable at a cost which for simplicity is assumed to take the iceberg form, whereby an amount $T_{ij} > 1$ must be shipped from location i to j in order for one unit to arrive.

With constant elasticity of demand, the profit-maximizing price of each variety is a constant mark-up over marginal cost, with the size of the mark-up equal to $\sigma/(\sigma\text{-}1)$, where σ is the elasticity of substitution between varieties. Since trade costs take the iceberg form, the cost inclusive of freight (cif) price of a variety in the consuming location will equal the free on board (fob) price of the variety at the point of production times the trade cost factor: $p_{ij} = T_{ij}\, p_i$. Production is assumed to involve increasing returns to scale, with a fixed cost and constant marginal cost. Free entry into manufacturing together with the pricing rule imply that equilibrium output of each variety will equal a constant $\bar{x}$, which corresponds to the value of output needed for firms to break even given the mark-up of price over marginal cost.

Two relationships in the model will prove especially useful for thinking about the implications of economic geography for spatial income inequality. The first is an equation for bilateral trade flows between each producing location i (exporter i) and each consuming location j (importer j). From the standard CES demand function, the equilibrium value of bilateral trade is:

$$n_i\, p_i\, x_{ij} \;=\; n_i\, p_i^{1-\sigma} \left(T_{ij}\right)^{1-\sigma} E_j\, G_j^{\sigma-1} \; . \tag{1}$$

This gravity equation relationship implies that bilateral exports from i to j depend on three sets of considerations. These include characteristics of the exporter—the number of manufacturing varieties produced (n_i) and the price of each variety (p_i)—which we

[2] For a full exposition of the model, see Fujita et al. (1999) Chapters 4 and 14. For a more detailed discussion of the implications for spatial income inequality, see Redding and Venables (2004).

summarize in the concept of *supply capacity* $\left(s_i \equiv n_i p_i^{1-\sigma}\right)$. They also include characteristics of the importer—expenditure on manufactures (E_j) and the price index (G_j) capturing the price of competing varieties in the import market—which we summarize in the concept of market capacity ($m_j \equiv E_j G_j^{\sigma-1}$). Finally, they depend on trade costs (T_{ij}) which vary bilaterally with both the exporter and importer.

The second relationship is the most central to our concerns and pins down the equilibrium price of the geographically immobile factor of production. In order to make zero equilibrium profits, the representative manufacturing firm in location *i* must sell $\overline{x}$. Therefore, the equilibrium price charged by this representative firm (p_i) must be sufficiently low that such that, given demands in all markets, it sells $\overline{x}$. From the CES demand functions in all markets, this equilibrium price is:

$$p_i^{\sigma}\overline{x} = \sum\nolimits_{j-1}^{R} E_j G_j^{\sigma-1}\left(T_{ij}\right)^{1-\sigma}. \tag{2}$$

Since equilibrium prices are a constant mark-up over marginal cost, it follows that the representative firm's marginal costs must be sufficiently low in order for it to sell this quantity. Firms' costs are assumed to depend on the price of a geographically immobile factor of production (w) which we term labour (though in reality it is a composite of all immobile factors of production); the price of a geographically mobile factor which we interpret as capital and whose return is equalized across all locations (v); and the price of intermediate inputs (G) which are manufacturing varieties that may be traded at a cost and are modelled as entering firms' cost functions with the same functional form as which they enter consumers' utility. In the interests of tractability, we consider the case where both fixed and variable costs are Cobb-Douglas in these three factors.

Substituting for equilibrium prices using the constant mark-up rule, yields the manufacturing wage equation which pins down the maximum wage that a representative firm in location *i* can afford to pay consistent with selling $\overline{x}$ and making zero equilibrium profits:

$$\left(w_i^{\beta} v_i^{\gamma} c_i\right)^{\sigma} = A G_i^{-\alpha\sigma} \sum\nolimits_{j}^{R} E_j G_j^{\sigma-1} T_{ij}^{1-\sigma}, \tag{3}$$

where A is a constant which collects together model parameters; α is the share of intermediate inputs in costs; β is the share of labour (geographically immobile); γ is the share of capital (geographically mobile); and c_i is a parameter which allows for differences in technology across locations.

The equilibrium wage (w_i) depends on levels of demand in all markets, which are determined by market capacity in each market $\left(m_j \equiv E_j G_j^{\sigma-1}\right)$ and bilateral trade costs (T_{ij}) which dictate the price of a variety produced in exporter i in importer j. It also depends on the price of the geographically mobile factor of production ($v_i = v$), which is the same across all locations and hence does not play a role in shaping spatial income inequality. Finally, the equilibrium wage also depends on the price of intermediate inputs as captured in the manufacturing price index (G_j), which can be shown to depend on supply capacity in each exporter $\left(s_i \equiv n_i p_i^{\sigma-1}\right)$ and on bilateral trade costs (T_{ij}) to each of these points of supply:

$$G_j = \left[\sum_i \left(p_i T_{ij}\right)^{1-\sigma}\right]^{1/(1-\sigma)}. \tag{4}$$

Firms based in locations that are close to large markets where there is little competition will be able to charge higher prices for their varieties and still sell $\bar{x}$ units of output, enabling them in equilibrium to pay higher nominal wages. This is the market access benefit of a central location. At the same time, firms based in locations that are close to sources of supply face lower post-transport costs of intermediate inputs, enabling them in equilibrium to pay higher nominal wages while still charging a price sufficiently low to sell $\bar{x}$ units of output. This is the supplier access benefit of a central location. Since all manufacturing varieties are demanded both by final consumers and as intermediate inputs, locations with good market access will tend to have good supplier access and these two mechanisms reinforce one another.

Thus, standard theoretical models of economic geography yield the prediction of a spatial income gradient in the nominal price of geographically immobile factors of production. Nominal wages should be higher in central locations and lower in those that are more peripheral. Since the price index is lower in central locations, not only are nominal wages higher but so are real wages. Clearly, this real wage differential can only be sustained in equilibrium because of the assumption that labour and possibly other factors of production are geographically immobile.

One line of the economic geography literature, following Krugman and Venables (1995) and Venables (1996), makes the assumption of geographic immobility for at least some factors, and this factor immobility provides an important force for the dispersion of economic activity, offsetting the agglomeration forces associated with transport costs, increasing returns to scale and input-output linkages. This line of research is most often thought of as applying across countries where labour mobility in particular is relatively low.

A second line of the economic geography literature, following Krugman (1991) and Helpman (1998), allows geographical mobility of all factors of production used in the manufacturing sector, but introduces an alternative force for the dispersion of economic activity. In the case of Krugman (1991), this is provided by immobile agricultural labourers which provide a potential incentive to move to the periphery in the presence of trade costs. In the case of Helpman (1998), this is provided by a geographically immobile housing stock, whose price varies across locations in equilibrium. This line of research is most often thought of as applying within countries where labour mobility is typically much greater than across countries. In Helpman (1998) geographic mobility of labour ensures that real wages are equalized across locations, but there remains a spatial income gradient in nominal wages. The higher market and supplier access of central locations results in higher nominal wages and an inflow of workers. This inflow of workers bids up the price of immobile housing in central locations until real wages are equalized.

Which locations are central and which are peripheral is itself determined endogenously within the model. The full general equilibrium involves specifying factor endowments and hence factor market clearing to determine income and expenditure (E_i), the output levels of each country's manufacturing (the values of n_i), output in all other sectors, and payments balance. Typically, this class of models displays multiple equilibrium where, depending on either the accidents of history or the vagaries of expectations, economic activity can end up agglomerating in multiple alternative regions. In the remainder of this paper, we take the location of economic activity (the E_i and n_i) as exogenous and examine the implications for spatial variation in the nominal incomes of geographically immobile factors. That is we examine whether, given the observed distribution of market and supplier access across locations, the spatial variation in nominal wages is as predicted by this class of models.

2. International evidence

2.1. Measuring market and supplier access

One of the key problems in taking the approach developed so far to the data is how to measure access to markets and sources of supply. This is particularly problematic as they depend on variables which are inherently hard to measure such as manufacturing price indices. One advantage of looking at the relationship between economic geography and factor incomes in the international arena is the availability of data on bilateral trade. Redding and Venables (2004) show how international trade data may be used to reveal unobserved market and supplier access and we begin by reviewing their approach.

Using the definitions of market capacity $\left(m_j \equiv E_j G_j^{\sigma-1}\right)$ and supply capacity $\left(s_i \equiv n_i p_i^{1-\sigma}\right)$ introduced above, the gravity equation for bilateral trade flows may be re-written as follows:

$$n_i p_i x_{ij} = s_i \left(T_{ij}\right)^{1-\sigma} m_j . \tag{5}$$

Given data on bilateral trade and measures of the determinants of trade costs (such as distance and the existence of a common border $T_{ij}^{1-\sigma} = dist_{ij}^{\delta_1} bord_{ij}^{\delta_2}$), market capacity and supply capacity can be modelled respectively by exporter and importer dummies. Including these dummies, equation (5) can be estimated and predicted values of market and supply capacity calculated. An important feature of this approach is that it explicitly controls for the manufacturing price index (G_j), which is termed "multilateral resistance" by Anderson and Van Wincoop (2003), and which enters here as a determinant of market capacity and hence bilateral trade flows.

Weighting estimated market and supply capacity by bilateral trade costs, overall measures of each exporter *i*'s market access (MA_i) and each importer *j*'s supplier access (SA_j) may be evaluated:

$$MA_i = \sum_j \left(T_{ij}\right)^{1-\sigma} m_j = \sum_j E_j G_j^{\sigma-1} T_{ij}^{1-\sigma},$$
$$SA_j = \sum_i s_i \left(T_{ij}\right)^{1-\sigma} = \sum_i n_i \left(p_i T_{ij}\right)^{1-\sigma}. \tag{6}$$

These measures of market and supplier access are, from the manufacturing wage equation (3) and the price index equation (4), precisely what determines the maximum wage that a manufacturing firm in location *i* can afford to pay consistent with zero equilibrium profits. Using the definitions above, the manufacturing wage equation can be re-written as:

$$\left(w_i^{\beta} v_i^{\gamma} c_i\right) = A\left(SA_i\right)^{\frac{\alpha\sigma}{\sigma-1}}\left(MA_i\right). \tag{7}$$

Having used data on bilateral trade to measure market and supplier access, Redding and Venables (2004) examine the extent to which these variables can explain cross-country variation in nominal incomes as predicted by manufacturing wage equation above. We now review their findings.[3]

2.2. Empirical evidence using theory-based measures

In reality, as discussed above, market and supplier access will be highly correlated, and so we focus here on the relationship between spatial income inequality and market access. Results incorporating supplier access produce similar conclusions as discussed in detail in Redding and Venables (2004). A variety of measures of the nominal income of immobile factors can be considered and we review here estimates based on GDP per capita as the left-hand side variable. Results using manufacturing wages per worker, available for a smaller sample of countries, are very similar. We begin by examining the par-

[3] These measures of market access and supplier access not only explain spatial income inequality but also provide the basis for a decomposition of export growth into the contribution of improvements in external market access and the contribution of enhancements in internal supply capacity. See Redding and Venables (2003) for further discussion.

tial correlation between market access and per capita income without controlling for cross-country variation in production technology, c_i. We then show that the results are robust to including measures of fundamental determinants of technology differences such as institutions and physical geography.

Table 1. Market access and GDP per capita

ln(GDP per capita) Obs Year	(1) 101 1996	(2) 101 1996	(3) 101 1996	(4) 101 1996
ln(FMA_i)	0.476** (0.066) [0.076]	-	-	-
ln(MA_i) = ln(DMA_i(1) + FMA_i)	-	0.558** (0.042) [0.064]	-	-
ln(MA_i) = ln(DMA_i(2) + FMA_i)	-	-	0.512** (0.048) [0.072]	-
ln(MA_i) = ln(DMA_i(3) + FMA_i)	-	-	-	0.395** (0.023) [0.035]
Estimation	OLS	OLS	OLS	OLS
R^2	0.346	0.642	0.552	0.732
F(·)	52.76	174.46	112.09	294.39
Prob>F	0.000	0.000	0.000	0.000

Notes: Reported results are from Redding and Venables (2004). First stage estimation of the trade equation using Tobit. Huber-White heteroscedasticity robust standard errors in parentheses. Bootstrapped standard errors in square parentheses (200 replications). FMA_i is Foreign Market Access excludes the own country market; DMA_i(1) is a first measure of Domestic Market Access, assuming internal trade costs are equal to the cost of shipping to a foreign country 100 km away and with a common border; DMA_i(2) combines information on internal distance with the coefficient on distance from the trade equation estimation to obtain a measure of Domestic Market Access that takes into account cross-country differences in internal areas; DMA_i(3) is the preferred measure of Domestic Market Access that uses internal area information but allows the coefficient on internal distance to be lower than that on external distance in the trade equation estimation. ** denotes statistical significance at the 5 per cent level; * denotes statistical significance at the 10 per cent level.

Column (1) of Table 1 reports the results of regressing log GDP per capita on a measure of log foreign market access, constructed as above but excluding the own market. This focuses on the relationship between spatial income inequality and access to markets other than one's own, and excluding the own market is a useful robustness test to ensure that results are not driven by omitted variables that influence both own market capacity and factor incomes. The estimated coefficient on foreign market access is positive and statistically significant at the 5 per cent level. Since the measures of market access and supplier access are generated from a prior regression (the equation for bilateral trade flows), bootstrap standard errors are reported in parentheses that take into account the presence of generated regressors. When included on its own, foreign market access alone explains approximately 35 per cent of the cross-country variation in GDP per capita.

Columns (2)-(4) report results for total market access (foreign plus domestic) using a variety of measures of domestic market capacity, corresponding to alternative assumptions about the value of internal trade costs. Column (2) assumes that internal trade costs are equal to the cost of shipping to a foreign country 100 km away and with a common border. Column (3) estimates internal area for each country using the formula for the internal area of a circular country, $dist_{ii} = 0.66(area/\pi)^{1/2}$, and assumes the costs of shipping a good a given distance internally are the same as the costs of shipping the good the same distance externally. Column (4) is the preferred specification, which exploits the formula for internal area and assumes a lower costs of shipping goods a given distance internally. In all cases, the estimated coefficient on total market access is positive and highly statistically significant. In Column (4) total market access alone explains approximately 70 per cent of the cross-country variation in GDP per capita.

Figures 1 and 2 plot log GDP per capita against foreign market access and the preferred measure of total market access. Each country is indicated by a three-letter code (see appendix 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 US). Once the size of the domestic market is controlled for, as in Figure 2, these countries are no longer outliers and we observe an even closer relationship between market access and spatial income inequality.

Figure 1. GDP per capita and FMA

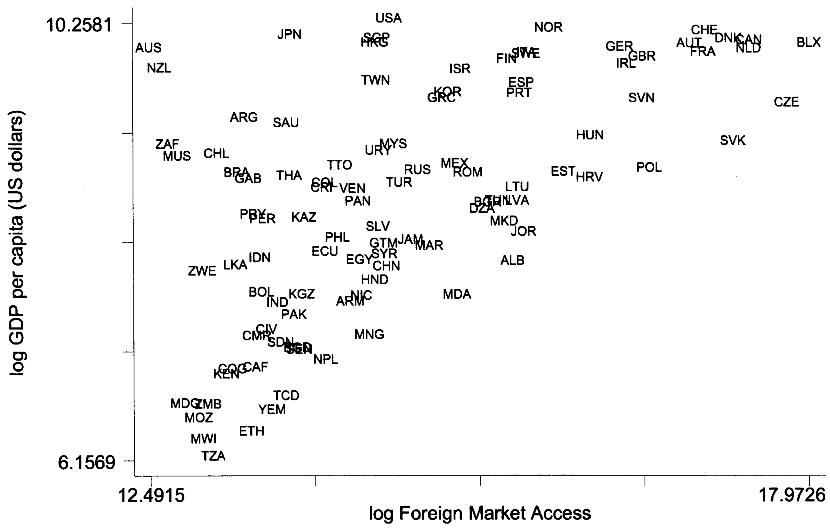
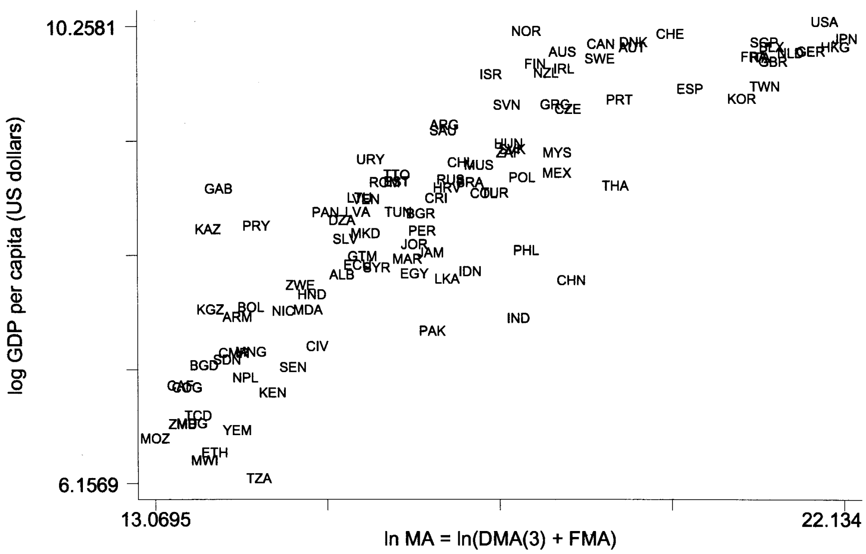


Figure 2. GDP per capita and MA=DMA(3) + FMA



While this evidence is extremely supportive of the mechanisms emphasized in the theoretical model, there remains the concern that there may be unmodelled (third) variables that are correlated with both market/supplier access and manufacturing wages. Redding and

Venables (2004) consider a wide range of control variables to demonstrate that the results are robust to controlling for variation in institutions and physical geography, which have been proposed as fundamental determinants of income per capita in the growth literature (for example, Acemoglu et al., 2001; Gallup et al., 1998, 2000; Hall and Jones, 1999; Knack and Keefer, 1997), and which may influence wages in the model through cross-country variation in technology. They also report the results of instrumental variables estimation based on distance to the three main markets and sources of supply around the world (distance to the US, distance to Japan and distance to Belgium as a central point in the EU) and undertake a whole series of experiments that demonstrate how the results are capturing the geography of access to markets and sources of supply. To emphasize the importance of access to markets other than one's own, we focus here on results using foreign market access.

The control variables considered include measures of countries' primary resource endowments. These include arable land area per capita, hydrocarbons per capita and a broader measure of mineral wealth. We also control for two other features of physical geography emphasised in the work of Gallup, Sachs and Mellinger (1998, 2000): the fraction of a country's land area in the geographical tropics and the prevalence of malaria. Finally, a number of studies have emphasized the role of institutions, "social capability", or "social infrastructure" in determining levels of per capita income.[4] Therefore, we augment the specification further by considering a number of other institutional, social and political characteristics of countries. These are a measure of the risk of expropriation or protection of property rights (perhaps the most widely-used measure of institutions or "social capability"), socialist rule during 1950-95 and the occurrence of an external war.

[4] See, for example, Acemoglu et al. (2001); Hall and Jones (1999); and Knack and Keefer (1997).

Table 2. Economic geography, physical geography, institutions, and GDP per capita

ln(*GDP per capita*)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Obs	**91**	**91**	**101**	**69**	**69**
Year	**1996**	**1996**	**1996**	**1996**	**1996**
ln(*FMA*$_i$)	0.215** (0.063)	0.229** (0.083)	0.148** (0.061)	0.269** (0.112)	0.189** (0.096)
ln(Hydrocarbons per capita)	0.019 (0.015)	0.019 (0.015)	-	0.026 (0.018)	0.026 (0.018)
ln(Arable Land Area per capita)	-0.050 (0.066)	-0.050 (0.070)	-	-0.078 (0.085)	-0.107 (0.088)
Number of Minerals	0.016** (0.008)	0.016 (0.010)	-	0.015 (0.014)	0.012 (0.014)
Fraction Land in Geog. Tropics	-0.057 (0.239)	-0.041 (0.257)	-	0.175 (0.294)	0.077 (0.286)
Prevalence of Malaria	-1.107** (0.282)	-1.097** (0.284)	-	-1.105** (0.318)	-1.163** (0.325)
Risk of Expropriation	-0.445** (0.091)	-0.441** (0.093)	-	-0.361** (0.116)	-0.376** (0.116)
Socialist Rule 1950-95	-0.210 (0.191)	-0.218 (0.192)	-	-0.099 (0.241)	-0.069 (0.248)
External War 1960-85	-0.052 (0.169)	-0.051 (0.174)	-	-0.078 (0.209)	-0.093 (0.210)
Full sample	yes	yes	yes		
Non-OECD				yes	
Non-OECD + OECD FMA					yes
Regional Dummies			yes		
Sargan (*p*-value)	-	0.980	-	-	-
Estimation	OLS	IV	OLS	OLS	OLS
R^2	0.766	0.766	0.688	0.669	0.654
F(·)	47.77	53.00	58.00	18.23	17.80
Prob>F	0.000	0.000	0.000	0.000	0.000

Notes: Reported results are from Redding and Venables (2004). First stage estimation of the trade equation using Tobit. Bootstrapped standard errors in square parentheses (200 replications). FMA_i is Foreign Market Access excluding the own country market; $DMA_i(3)$ is the preferred measure of Domestic Market Access (see Table 1). The regional dummies in Column (3) are Sub-Saharan Africa, North Africa and the Middle-East, Latin America and the Caribbean, South-East Asia, Other Asia, and Eastern Europe and the former USSR. The excluded exogenous variables in Column (2) are log distance from the US, from Belgium, and from Japan. Sargan is a Sargan test of the model's overidentifying restrictions. Columns (4) and (5) present results from estimation on the non-OECD. In Column (4), *FMA* is computed using all countries, and in Column (5), *FMA* is computed excluding non-OECD countries. ** denotes statistical significance at the 5 per cent level; * denotes statistical significance at the 10 per cent level.

Column (1) of Table 2 reports estimation results from Redding and Venables (2004) including the control variables. The availability of the data on hydrocarbons per capita and the risk of expropriation reduces the sample to 91 countries. The estimated market access coefficient remains positively signed and highly statistically significant. Among the control variables, the coefficients on the prevalence of malaria and risk of expropriation are negatively signed and statistically significant at the 5 per cent level. These findings are entirely consistent with the theoretical model presented above if the effect of malaria and lack of protection of property rights is to reduce levels of technical efficiency, as indeed is argued in the literature on cross-country income differences.

Column (2) reports instrumental variables estimation for this specification, where foreign market access is instrumented with distance from the US, distance from Japan and distance from Belgium. The instruments are highly statistically significant in the first-stage regression: the *p*-value for an *F*-test of the null hypothesis that the coefficients on the excluded exogenous variables are equal to zero is 0.00 and the three instruments explain 88 per cent of the variation in foreign market access. In the second-stage wage equation, the effect of foreign market access remains positive and highly statistically significant, with the IV estimate close to the OLS value.

The validity of the instruments is examined using a Sargan test of the model's overidentifying restrictions and the null hypothesis that the excluded exogenous variables are uncorrelated with the wage equation residuals cannot be rejected. These results provide evidence that the estimated market access effects are not being driven by unmodelled (third) variables missing from our list of controls and correlated with both market access and GDP per capita. They provide support for the mechanisms emphasized by the theoretical model: namely that, after controlling for the exogenous determinants of technology, distance from these three main centres of economic activity matters for GDP per capita through market access.

Rather than seeking to explicitly model the fundamental determinants of technology, column (3) considers an alternative non-parametric approach where the economic variables are replaced with a full set of region dummies.[5] The dummies control for all observed and unobserved heterogeneity across regions, so parameters of inter-

[5] The regions are Sub Saharan Africa; North Africa and the Middle-East; Latin America and the Caribbean; South East Asia; Other Asia; Eastern Europe and the former USSR; where the excluded category is the industrialised countries of North America, Western Europe and Oceania.

est are identified solely from variation in market access within regions. The estimated coefficients on the 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 coefficient on foreign market access remains positive and highly statistically significant. Thus, even if the relationship between market access and per capita income is identified only using variation within regions, we observe a similar pattern of results.

Column (4) establishes that the results are not driven by the OECD. If the model is re-estimated for non-OECD countries alone, the coefficient on foreign market access remains positive and highly statistically significant. Column (5) undertakes a further robustness test, estimating the model for the sample of non-OECD countries, and calculating foreign market access by only exploiting information on market capacity in OECD countries weighted by trade costs. Here, we examine the extent to which variation in income per capita across non-OECD countries can be explained by differential access to OECD markets, and again find a similar pattern of results.

In each of these specifications, as well as in a variety of further robustness tests undertaken in Redding and Venables (2004), measures of access to markets and sources of supply constructed using the structure of a theoretical economic geography model play a statistically significant and economically important role in explaining international inequality. Redding and Schott (2003) argue that there may be an important additional indirect effect of economic geography on spatial income inequality because access to markets and sources of supply also shape incentives to invest in human capital.

2.3. Other international evidence

A variety of other studies provide support for the idea that economic geography has an important role to play in explaining international income variation. The idea that access to markets is important dates back at least to Harris (1954), who argued that the potential demand for goods and services produced in any one location depends upon the distance-weighted GDP of all locations. Hummels (1995) finds that the residuals from the augmented Solow-Swan neoclassical model of growth are highly correlated with three alternative measures of geographical location. Leamer (1997) extends traditional market access measures to improve their treatment of the domestic market and by exploiting information on the distance coefficient from a gravity model. He finds that Central and Eastern European countries' differing access to Western European markets creates differences in their potential to achieve higher standards of living.

Gallup et al. (1998, 2000) and Radelet and Sachs (1998) find that measures of physical geography (e.g. fraction of land area in the geographical tropics) and transport costs (e.g. percentage of land area within 100 km of the coast or navigable rivers) are important for cross-country income. Though the focus is not on market access per se, Frankel and Romer (1999) use geography measures as instruments for trade flows. They find evidence of a positive relationship between per capita income and exogenous variation in the ratio of trade to GDP due to the geography measures.

3. Intra-national evidence

Wage gradients can be estimated on sub-national as well as international data, and Hanson (1998a, 2000) performs such an estimation using a panel of US counties. His specification is based on the wage equation (3) excluding intermediate inputs. The basic model is estimated using county data on average earnings, and taking as independent variable the aggregate income of counties in a set of concentric circles at increasing distance around each observation, each distance weighted according to a factor $\exp\left(\beta_2 dist_{ij}\right)$, (where this weighting factor corresponds to $\left(T_{ij}\right)^{1-\sigma}$. The equation is estimated in first differences so that any time-invariant features of counties are swept out. Hanson finds a powerful wage gradient effect, with his measure of market access having a positive effect on earnings, and within this measure, distance (coefficient β_2) having a highly significant effect.

In an augmented model, Hanson addresses the endogeneity of the price index, G_j, by assuming that labour is perfectly mobile across counties (as in Krugman, 1991), so that real wages are equalized. Choosing the real wage in one location as the numeraire, the real wage in all locations must equal one. Hypothesizing that housing is the only immobile factor (as in Helpman, 1998), and that it takes a fixed share 1-μ of income, real wages are $w_j / G_j^{\mu} P_j^{1-\mu}$ where P_j is the price of housing (so the denominator is the cost of living index in country j). The value of housing expenditure satisfies

$P_j H_j = (1-\mu)Y_j$ where H_j is the (exogenous) housing stock, so the equilibrium value of the price index is

$$G_j^{\mu} = w_j \left(\frac{(1-\mu)Y_j}{H_j} \right)^{\mu-1}. \tag{8}$$

Using this in the wage equation (3), together with manufacturing expenditure $E_j = \mu Y_j$ and setting $\alpha = 0$ yields the following estimating equation,

$$\ln w_i = \xi + \sigma^{-1} \ln \left(\sum_j^R Y_j^{\frac{\sigma(\mu-1)+1}{\mu}} H_j^{\frac{(1-\mu)(\sigma-1)}{\mu}} w_j^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)dist_{ij}} \right) + u_i, \tag{9}$$

where transport costs are modelled as an exponential function of distance: $T_{ij} = e^{\tau dist_{ij}}$.

Columns (1) and (2) of Table 3 present the results of estimating this specification using non-linear least squares for the periods 1970-80 and 1980-90. All variables are signed according to economic priors and are highly statistically significant. The inclusion of controls for the manufacturing price index, G_j, is found to improve the fit of the regression. The estimated values of the elasticity of substitution, σ, are broadly consistent with independent econometric estimates of this parameter, and are found to have fallen between the two sample periods. As implied by theory, the estimated expenditure share on tradable goods, μ, lies between 0 and 1, although a value above 0.9 is somewhat high. The estimated value of transport costs, τ, rises over time, and this may reflect a shift in production away from low-transport-cost manufactures to high-transport-cost services during the sample period. The estimated values of σ imply a mark-up factor of price over marginal cost that ranges between 1.15 and 1.25.[6]

[6] These estimates imply a value of $\sigma/(\sigma\text{-}1)$ of greater than 1, and are thus consistent with increasing returns to scale. In Helpman (1998), the value of $\sigma(1\text{-}\mu)$ is crucial for the determinants of agglomeration. All the parameter estimates in Table 3 imply a value of $\sigma(1-\mu)<1$, so that an increase in transport costs increases the likelihood of agglomeration.

Table 3. Market potential and wages across US counties

	(1)	(2)	(3)
Obs	**3705**	**3705**	**3705**
Time Period	**1970-80**	**1980-90**	**1980-90**
σ	7.597	6.562	4.935
	(1.250)	(0.838)	(1.372)
μ	0.916	0.956	0.982
	(0.015)	(0.013)	(0.035)
τ	1.970	3.219	1.634
	(0.328)	(0.416)	(0.523)
Wage controls	no	no	yes
Adj. R^2	0.256	0.347	0.376
Log Likelihood	-16698.1	-16576.9	-16479.9
Schwarz criterion	-16714.0	-16592.9	-16575.5

Notes: Reported results are from Hanson (2000). Estimation is by non-linear least squares. Sample is all US counties in the continental US, and the equation estimated is the time-difference of equation (13). All variables are scaled relative to weighted averages for the continental US. The dependent variable is the log change in average annual earnings from Regional Economic Information System (REIS), US BEA. Regional income is total personal income from REIS. The housing stock is measured by total housing units from the US Census of Population and Housing. The specification in column (3) includes controls for human capital, demographic characteristics, and exogenous amenities. Heteroscedasticity-consistent standard errors are in parentheses. The Schwartz Criterion is written as $ln(L) - k*ln(N)/2$, where k is the number of parameters.

The time-differenced specification controls for unobserved heterogeneity across counties in the level of manufacturing wages. However, it could be that wages have risen faster in counties with favourable exogenous amenities (e.g. weather or natural geography) or that have accumulated human capital (both through the private rate of return to human capital acquisition and through any externalities) and that these omitted variables are correlated with changes in market access. Since human capital accumulation may, in part, be determined by economic geography, it is not clear that one wants to exclude this component of the change in wages from the analysis. However, Hanson (2000) shows that his results are robust to including a whole range of controls for levels of human capital, demographic composition of the working age population, and exogenous amenities. Results including these controls are shown for the main estimation sample for the period 1980-90 in column (3).

Dekle and Eaton (1999) provide evidence on wage and land rent gradients from another context, exploiting data on Japanese prefectures. The wage and land rent data are used to estimate the effect of the agglomeration of economic activity on measured productivity. Relocating value-added 100 km away is found to reduce its impact on productivity by 9 per cent in Finance and 1 per cent in Manufacturing. Combes and Lafourcade (2001) examine the impact of transport cost declines on regional inequality within France, and also provide evidence supporting geography's role in shaping income inequality within countries. Breinlich (2003) undertakes an analysis of variation in real wages across European NUTS-2 regions and presents evidence of a close relationship with measures of market access. In perhaps one of the most detailed intra-national studies to date, Amiti and Cameron (2004) exploit highly disaggregated micro-data for Indonesia and the input-output matrix to construct measures of market and supplier access, and to document their importance in explaining variation in wages.

4. Natural experiments

The empirical results surveyed so far provide econometric evidence of wage gradients across geographical space (both across and within countries) consistent with the predictions of economic geography models. Ceteris paribus, locations that are remote from markets and sources of supply of intermediate inputs are characterised by lower nominal wages. As always, there remain potential concerns relating to identification and simultaneity that could be resolved by observing a controlled or natural experiment that generates exogenous variation in market and supplier access. In the remainder of this subsection, we discuss a group of papers that have exploited natural experiments to identify the effects of the geography of access to markets and sources of supply.

In 1985 Mexico opened its economy to international trade, bringing to an end four decades of import-substitution industrialization. Hanson (1996, 1998b) finds that trade reform has contributed towards the break-up of the traditional manufacturing belt centred on Mexico City and the formation of new industry centres in Northern Mexico. For example, in the apparel industry Hanson (1996) finds that prior to trade liberalization, production was concentrated around Mexico City and largely orientated towards the Mexican market, with design and marketing concentrated in Mexico City and assembly in the neighbouring states. With trade liberalization, there was a substantial relocation of manufacturing activity towards the US border, and the nature of manufacturing activity was also reorientated—away from domestic production towards offshore assembly for foreign (largely US) firms. There is evidence of a negative relationship between relative wages and distance from Mexico City prior to 1988, and of a statistically significant decline in the size of the estimated coefficient on distance from Mexico City between 1985 and 1988.[7] This provides support for the existence of a regional wage gradient centred on Mexico City prior to trade liberalization and of the partial breakdown of this regional wage gradient as production re-orientated towards the US.

Hanson (1997) analyses the determinants of state relative to national manufacturing wages for a panel of two-digit Mexican manufacturing industries over the period 1965-88. Nominal wages are found to be negatively correlated with both distance from Mexico City and distance from the Mexico-USA border. A 10 per cent increase in distance from Mexico City is associated with a 1.9 per cent reduction in the relative state wage, while the same increase in distance from the Mexico-USA border is associated with a 1.3 per cent reduction.

Overman and Winters (2004) use the accession of the UK to what was then the European Economic Community (EEC) in 1973 as an exogenous source of variation in access to markets and sources of supply. As trade re-orientated towards EU markets, they find a systematic shift in the location of economic activity within the UK towards ports which trade more intensively with EU partners (such as Dover or Folkestone).

Redding and Sturm (2005) use the division and re-unification of Germany as a natural experiment that changes the relative market and supplier access of West German cities close to what became the East-West German border. These cities move from being at the heart of an integrated Germany during the pre-war period, to being on the very edge of the Western world during the cold-war, and then to being

[7] To isolate regional wage differentials that are specific to the Apparel industry, the data on wages in Apparel sector in each state relative to Mexico City are normalised by average manufacturing wages in each state relative to Mexico City. Similar estimation results are found using un-normalized wages. See Hanson (1996) for further discussion.

back at the heart of Germany following re-unification in 1990. Comparing the inter-war and cold-war periods in particular, they find a decline in the size of West German border cities relative to other West German cities. This is consistent with the line of economic geography research emphasizing factor mobility within countries and the role of non-traded housing (Helpman 1998). As market and supplier access in cities close to the border falls relative to cities further away, the decline in relative nominal and real wages leads to an outflow of population until the price of non-traded housing adjusts to equalize real wages.

5. Conclusions

Despite high levels of integration of goods and financial markets, spatial variation in income per capita and wages within and between countries has not been arbitraged away by the mobility of firms and plants. There are many potential reasons for the reluctance of firms to move production to low wage locations, one of which is remoteness from markets and sources of supply. Transport costs and other trade frictions mean that firms in peripheral locations suffer a market access penalty on their sales and face additional costs on imported inputs. As a consequence, firms in these countries can only afford to pay relatively low incomes to immobile factors—even if, for example, their technologies and the institutional framework within which they operate are the same as elsewhere.

This paper has surveyed the empirical literature which has sought to quantify the importance of these effects. Using both international and intra-national data, evidence was found of a statistically significant and economically important relationship between access to markets and sources of supply and the income paid to geographically immobile factors of production. These findings are robust across a variety of specifications, to instrumental variables estimation, and to a variety of further robustness tests. Results from natural experiments exploiting exogenous variation in economic integration provided further support to this body of econometric evidence.

The results surveyed here 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.

While countries obviously cannot move, and thereby reduce their physical distance, it is possible to reduce the costs of remoteness. Examples include efforts to reduce transport costs directly via improvements in infrastructure (e.g. roads, ports, etc.). New technologies—such as Information and Communication (ICTs) technologies or even low-cost, long-distance, wide-bodied jet aircraft such as the Boeing 747—may also have a role to play in enabling locations to escape the travails of life on the periphery, at least for certain kinds of economic activities.

As transport costs and other trade frictions fall, some economic activities move to low wage locations—as trade costs fall, it becomes more profitable for manufacturing firms to produce in remote locations and equilibrium nominal wages there rise. However, there is likely to be great heterogeneity in the kinds of economic activities that move to low wage locations. Understanding this heterogeneity—which activities move, where, and the implications for the source and the host country—is an important area for further research at the heart of recent popular debates concerning outsourcing and off-shoring.

Appendix

Country codes: Albania (ALB), Argentina (ARG), Armenia (ARM), Australia (AUS), Austria (AUT), Bangladesh (BGD), Bulgaria (BGR), Belgium/Luxembourg (BLX), Bolivia (BOL), Brazil (BRA), Central African Republic (CAF), Canada (CAN), Switzerland (CHE), Chile (CHL), China (CHN), Cote d'Ivoire (CIV), Cameroon (CMR), Congo Republic (COG), Columbia (COL), Costa Rica (CRI), Czech Republic (CZE), Germany (DEU), Denmark (DNK), Algeria (DZA), Ecuador (ECU), Egypt (EGY), Spain (ESP), Estonia (EST), Ethiopia (ETH), Finland (FIN), France (FRA), Gabon (GAB), UK (GBR), Greece (GRC), Guatemala (GTM), Hong Kong (HKG), Honduras (HND), Croatia (HRV), Hungary (HUN), Indonesia (IDN), India (IND), Ireland (IRL), Israel (ISR), Italy (ITA), Jamaica (JAM), Jordan (JOR), Japan (JPN), Kazakhstan (KAZ), Kenya (KEN), Kyrgyz Republic (KGZ), South Korea (KOR), Sri Lanka (LKA), Lithuania (LTU), Latvia (LVA), Morocco (MAR), Moldova (MDA), Madagascar (MDG), Mexico (MEX), Macedonia (MKD), Mongolia (MNG), Mozambique (MOZ), Mauritius (MUS), Malawi (MWI), Malaysia (MYS), Nicaragua (NIC), Netherlands (NLD), Norway (NOR), Nepal (NPL), New Zealand (NZL), Pakistan (PAK), Panama (PAN), Peru (PER), Philippines (PHL), Poland (POL), Portugal (PRT), Paraguay (PRY), Romania (ROM), Russia (RUS), Saudi Arabia (SAU), Sudan (SDN), Senegal (SEN), Singapore (SGP), El Salvador (SLV), Slovak Republic (SVK), Slovenia (SVN), Sweden (SWE), Syria (SYR), Chad (TCD), Thailand (THA), Trinidad and Tobago (TTO), Tunisia (TUN), Turkey (TUR), Taiwan (TWN), Tanzania (TZA), Uruguay (URY), US of America (USA), Venezuela (VEN), Yemen (YEM), South Africa (ZAF), Zambia (ZMB), Zimbabwe (ZWE).

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